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A DECISION SUPPORT SYSTEM (DSS) FOR
AWACS PERSONNEL ACQUISITION MANAGEMENT

THESIS

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AFIT/GOR/ENS/90M-10

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Wright-Patterson Air Force Base, Ohio

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THESIS

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## Preface

Personnel acquisition planning for AWACS crew positions is currently based on "best guesses" driven by near term loss expectations. For this reason, managers largely restrict themselves to dealing with short term corrections in manning level deficiencies. Long term management is largely a matter of manager intuition. This research was conducted to extend management capabilities to handle long range acquisition planning in a structured environment.

The process of this research was fraught with difficulties and dead ends. That these were overcome is largely due to the guidance provided by my advisor, LtCol Skip Valusek (who I think could teach Machiavelli a few tricks).

Finally, I owe a debt of thanks to my wife Robin, for her support and understanding throughout my AFIT experience, and a debt pure and simple to my children, upon whom I will lavish attention, now that I am done here.

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## Abstract

~ The purpose of this research was to define an appropriate tool to
assist AWACS personnel managers in determining the personnel
acquisitions that are required for AWACS operations. The approach used
to structure the decision process was that of a Decision Support System
(DSS). The goal of the specified DSS was to provide an initial point to
better state personnel acquisition requirements, particularly with
regard to the experience of the crew force, and to provide a structure
for improvement in the DSS itself.

The decisions supported by the designed DSS go beyond what has
been attempted by AWACS air crew managers in the past, explicitly
addressing experience level inventories and the need to stabilize both
manning levels and experience levels in the various AWACS crew
positions. The overall design of the DSS to support these goals is
specified through the mechanisms of concept mapping and storyboarding,
and a kernel system is developed. Adaptive design is adopted as the
means for continued system development and evolution.

# A DECISION SUPPORT SYSTEM (DSS) FOR AWACS PERSONNEL ACQUISITION MANAGEMENT

## I. Introduction

### Background

The Airborne Warning and Control System (AWACS) is an air battle management system. Its functions are to provide airborne surveillance and to control friendly aircraft in air battles in its surveillance area. These functions are tactical in nature; therefore, AWACS belongs to the Tactical Air Command (TAC), with the 28th Air Division (28 AD) at Tinker AFB providing primary management of the system.

While the functions of AWACS are tactical, the personnel requirements of the system are largely alien to TAC. TAC is primarily oriented to fighter aircraft with one or two rated crew positions. AWACS, in contrast, has 12 crew positions (Table 1), only two of which are rated. Managing this diverse crew force requires the ability to plan new personnel acquisitions for each crew position with enough accuracy to keep the crew force "stable" (i.e., maintain manning and experience levels near nominal values). One of the consequences of the TAC/AWACS personnel orientation mismatch is an absence of management tools to support the personnel acquisition planning process across the entire spectrum of AWACS crew positions. It is this absence of management tools in the AWACS personnel management system which is the concern of this study.

**Table 1** -- AWACS Crew Component Information[**]

| | | | Authorizations | |
|---|---|---|---|---|
| Flight Crew Positions | | #/Crew | Line | Staff |
| 1. Pilot[*] | (P/CP) | 2 | 103 | 18 |
| 2. Navigator[*] | (NAV) | 1 | 50 | 14 |
| 3. Flight Engineer | (FE) | 1 | 55 | 3 |
| | | | | |
| Mission Crew Positions | | | | |
| 4. Mission Crew Commander | (MCC) | 1 | 78 | 28 |
| 5. Senior Director | (SD) | 1 | 50 | 9 |
| 6. Weapons Director | (WD) | 4 | 238 | 8 |
| 7. Air Surveillance Officer | (ASO) | 1 | 54 | 8 |
| 8. Air Surveillance Technician | (AST) | 3 | 219 | 23 |
| 9. Communications System Operator | (CSO) | 1 | 101 | 6 |
| 10. Communications Technician | (CT) | 1 | 50 | 6 |
| 11. Computer Maintenance Technician | (CDMT) | 1 | 50 | 6 |
| 12. Airborne Radar Technician | (ART) | 2 | 100 | 5 |

[*] Rated Positions
[**] Mod 30-35

## Programmed Flying Training

The Programmed Flying Training (PFT) program is a personnel management effort originally designed to allow major commands to identify new requirements for rated officers to the Air Training Command (ATC). It was later expanded to cover non-rated crew positions. The stated goal of the PFT program is to "sustain an inventory ... to meet requirements while retaining a credible combat posture" [Dept of the Air Force, AF Planning Document, Change 6 : 3]. For any weapons system manned through the PFT, this amounts to maintaining each crew position at an adequate manning level *with an experience profile that is sufficient to ensure the system is effective.* Assuming ATC can provide the training capacity to fill the requirements identified by the major commands, the PFT may be capable of achieving its stated goals. However, regardless of ATC capabilities, the PFT can only function

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properly *if the requirements identified by the major command's are accurate.* Accurate requirements identification requires that personnel managers have adequate management tools that allow them to properly identify personnel needs. These tools have never been developed fully, particularly for the non-rated positions. Major factors in the lack of development of management tools for the non-rated positio *у* have been the lack of good criteria for measuring the experience level of the force and the specialized (small sized) nature of the positions.

**AWACS and the PFT.** Under the current AWACS PFT process, the 28 AD hosts annual PFT conferences and quarterly review conferences at Tinker AFB to plan new crew acquisitions for a five year period. Participants are from TAC, the Air Force Military Personnel Center (AFMPC) and the 28 AD. These three participants produce a consensus figure for the appropriate numbers of new acquisitions required to keep the AWACS crew force healthy with the constraint that the desired acquisition is achievable. (By achievable, it is meant that constraints that bind each organization in the acquisition process are not violated, e.g., more bodies are not "bought" than TAC or AFMPC can afford, or more are not bought than the 28 AD can give final training to in a given acquisition cycle).

The primary 28 AD organization that deals with PFT issues consists of representatives from 1) the 552 Tactical Training Squadron (TTS) and the 966 Airborne Warning and Control Training Squadron (AWACTS), to cover 28 AD controlled training issues (i.e., annual capacities, changes, etc.), and 2) the personnel managers for each crew position, who are tasked with providing the basic information on which the whole

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PFT conference outcome is based, i.e., identifying the necessary new acquisitions needed to keep their respective crew positions "healthy".

For AWACS, the before-mentioned lack of appropriate personnel management tools has resulted in managers determining personnel requirements through the use of individually developed, unstructured heuristics. Each of the crew position managers has his own "rules" for arriving at a best guess; these rules are not stated anywhere, and change every time the manager for the position changes. For these managers, estimating needs is typically an exercise in maintaining a personal knowledge of all members of the crew force with respect to the factors that impact the manning status of the crew position (factors such as PCSs, separations, upgrades, ratings on evaluations, etc). This information is "filed" by each manager in his own unique format for his sole use. Fundamentally, the personnel requirements determination process is based on the manager's intuition.

Given the diversity of factors that impact the status of a crew position (discussed in the next section) and manager's lack of tools, it is not surprising that the personnel requirements identified by the managers are driven by short range considerations. Consequently, the crew positions suffer from severe long term fluctuations in total manning and in experience base. The manning fluctuations shown in Figure 1 are representative of fluctuations that have been detected in the AWACS crew force in past analyses of the crew force [Stone]. The shortfall from the authorized manning level is plotted at six month intervals. Of special note are the severe peaks at five year intervals. Under current planning processes, these peaks are built into the system,

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## PERCENT SHORTFALL FROM AUTHORIZED LEVEL
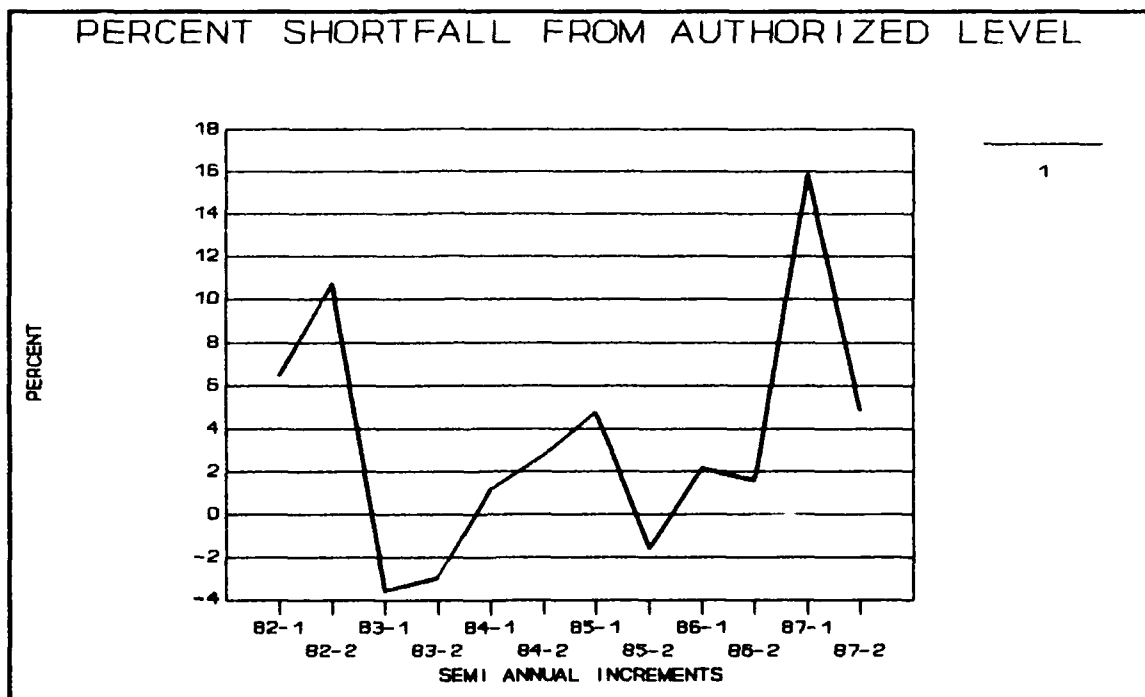


**Figure 1** -- Crew Position Manning Fluctuations (representative)

and are repeated every five years.

A comparable graph for experience level is not directly available, due to the lack of experience level criteria for most of the crew positions. However, it is instructive to look at the proportion of a crew position that is made up of first term personnel (for positions that acquire personnel through new Air Force accessions), as an indicator of the level of experience. For crew positions such as the WD position, there is a direct correlation between the periods of high manning in Figure 1 and a high representation of first term personnel in the crew position. This is to be expected, since acquisitions for this position have historically been made up of personnel new to the Air Force. A representative graph for this condition is shown in Figure 2. As in the previous figure, significant fluctuations in the data of interest (assuming the proportion of first term personnel is accepted as

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## PERCENT OF FIRST TERM PERSONNEL IN CREW POSITION
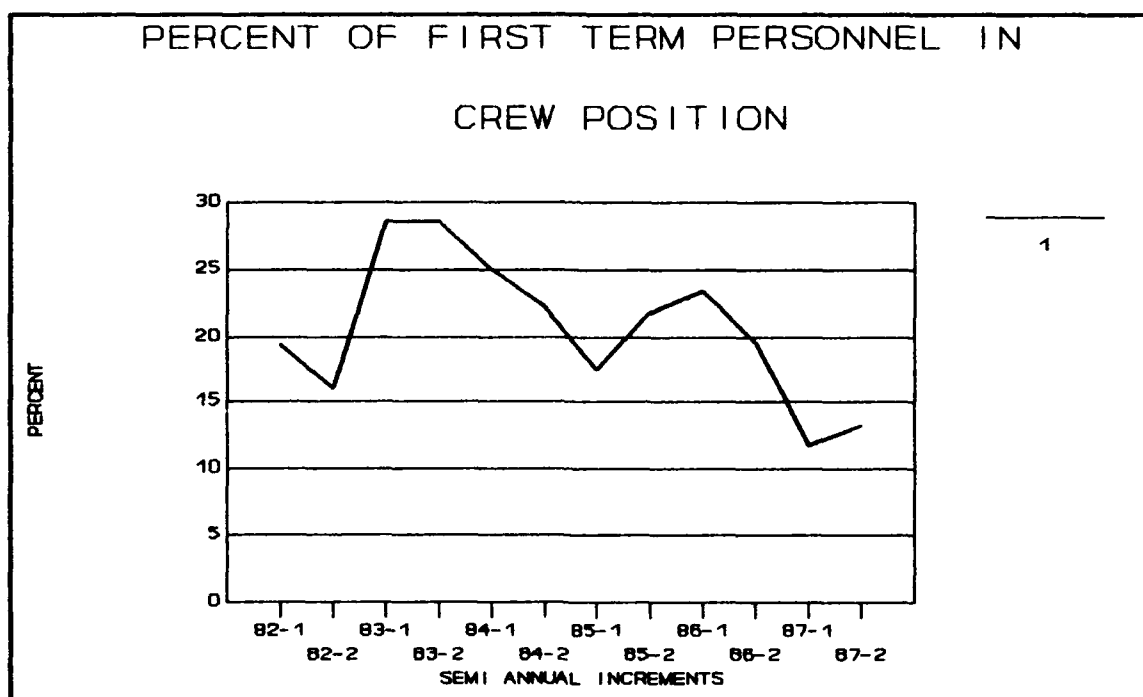


**Figure 2** -- First Term Personnel in AWACS Crew Positions (representative)

an indicator of overall experience in the crew position) are observed.

### AWACS Personnel Structure

AWACS' mission obligations and capabilities are determined by higher headquarters, and result from specific defense objectives (ranging from NATO support to showing the flag in hot spots around the world). Specific personnel authorizations for the system depend on the extent of the mission for which the system is responsible. The number of authorizations an air crew manager deals with varies by crew position. This number has four primary factors:

1) the number of members required in each position for a full crew;

2) the number of overhead positions authorized for staff functions;

3) the number of crews authorized per primary assigned aircraft (PAA), and;

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4) the number of PAA.

Keeping these authorizations filled is a basic part of the air crew
manager's function. The personnel acquisition requirements he
determines for the PFT are driven at a very basic level by the need to
predict when some of these authorizations will become vacant. However,
he must also deal with changes in authorizations. All four of the
factors that drive authorizations are subject to change. The creation
of new units requires new staff authorizations (e.g., the creation of
the 962 AWACS at Elmendorf AFB created new staff authorizations to
provide the squadron staff) and changing missions can alter crew
compositions, PAA and crew/PAA ratio (e.g., the transition of airframes
from Block 20-25 to Block 30-35 configuration, reflecting mission
requirements for more surveillance and control capacity. The change in
mission will require authorization increases of more than 25% for both
the WD and AST positions).

The AWACS crew positions were presented in Table 1. As stated,
there are 12 crew positions; all are required for AWACS to perform its
mission. The current authorizations for each crew position are also
presented in Table 1. Factors to note in the table are 1) the absolute
differences in number of personnel being managed in each crew position,
2) the number of personnel required per crew in the position, and 3) the
size of the staff authorization for each position. These factors are of
interest because they indicate the differences in problem scope faced by
the individual crew position managers who collectively are required to
keep the AWACS crew force healthy and the system mission effective. For
(1), the number of authorizations in different crew positions vary by a

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factor of close to five; some managers have many more people with whom they must maintain contact under current management methods. For (2), the number of authorizations per crew position per crew indicates that some positions have more leeway in their manning tolerances than others. This is also the case for (3), since positions with large staff authorizations have reserve personnel in the system to perform flying missions if shortages occur). These issues are discussed more extensively in the following section.

**Diversity of Factors among Crew Positions.** All of the AWACS crew positions must remain healthy for the system to perform its mission effectively. However, the considerations facing each position manager to achieve a healthy status for his position are not the same. A contrast of Pilots and Weapons Directors provides valuable insights into the differences in the factors that affect each crew position.

Pilots have well-defined performance factors that indicate the competence of individual crew members and that can be aggregated to indicate the experience level of the AWACS pilot crew force. Measures such as total flying hours, number of landings, number of touch-and-goes and number of air-refuelings accomplished provide a direct measure of the pilot's experience *because the pilot is exercising the skills that affect his experience level for every measure mentioned.* The pilot manager has reasonable measures for determining the experience profile of the crew position he manages.

In the numbers game, however, the pilot manager has severe problems predicting losses over time. Pilots have fairly extensive non-AWACS assignment opportunities (e.g., staff and command jobs and flying

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jobs on other airframes are filled by AFMPC with AWACS pilots). With
pilots in short supply Air Force wide, AFMPC juggles its supply of
pilots, often giving the losing organizations short notice. More
critical to the pilot manager however, is the demand for the pilot's
skills in the civilian sector. The myriad of factors that change the
demand for pilots in the civilian sector changes the "leak rate" the
manager must contend with, and generally, he has no way of predicting
these changes effectively.

The story for the WD manager is much different. In the experience
profile area, as an example, even though total flying hours are logged
for WDs as they are for pilots, flying hours may be a poor measure of
the individual's competence for the following reasons:

1) the time spent by the WD exercising his primary airborne
skills, i.e., controlling other aircraft, may only be a small fraction
of the total time he spends in the air; it is not uncommon for the WD to
control no aircraft due to factors such as weather and AWACS systems
malfunctions;

2) the work load an individual WD experiences is not uniform
because of different mission profiles; and

3) since there are multiple WDs on a given crew, the
accumulation of experience will, in general, not be uniform; for a
difficult control problem, the MCC may have his most experienced
operator be in charge of directing the problem.
This lack of good experience measures has resulted in the current
practice in the AWACS community of designating WDs as fully experienced
after they have been flying for one year following graduation from

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flight training at the 552 TTS. (In contrast, non-airborne WDs, operating at ground TACCs, are rated for experience by the number of controls they direct. With current data availability constraints, this is not an option for rating the AWACS WD force).

In the manning level arena, however, the WD manager is faced with a crew force that has limited non-AWACS assignment opportunities and almost no demand in the civilian sector for its military skills. Losses are much more predictable over a longer period of time in the WD crew force than they are in the pilot crew force.

In general, the management of each crew position entails consideration of a unique mix of factors. Some of the critical factors that have differing impacts on the different crew positions are:

1) Non-AWACS assignment opportunities -- the personnel system is closed for some crew positions (ARTs, AST) and crew losses are mostly due to separations (which are fairly predictable), while the system is open for others (P, FE, CDMT) and short notice PCS losses are a major factor in disrupting the position's manning stability. (Closed and open refer to whether the AFSC for a particular crew position is "unique" to AWACS. If the AFSC is closed, then the personnel in it are "trapped" in the AWACS personnel system).

2) Experience measures -- some crew positions have well-defined measures for determining experience of its members (e.g., Flight Deck), others have less well-defined measures (CDMT, ART), but operate in a technical area that lends itself to rather unambiguous measures (repair record), and still others have arbitrarily defined measures that provide no guidance (WD).

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3) Redundancy in the crew position -- AWACS mission capabilities are sensitive to crew positions. Crew positions that are manned one deep per crew can degrade system performance more rapidly than crew positions having multiple members per crew. If there are insufficient FEs, the E-3 will never get off the ground; if there are insufficient WDs, the system can still operate at some degraded level with a crew that is undermanned in the WD position.

4) Crew position independence -- manning of many of the crew positions can be managed totally independently of all of the other positions; the manager's only consideration is the health of the position he manages. Other positions are not independent. For example, a significant portion of the MCC force is drawn from the SD population, while almost all SDs come from the WD position. Therefore, the WD manager may be faced with a deficiency in WD manning because of a decision outside of his control to rob the WD personnel pool to fix the SD pool. Further, this deficiency is generally not only a numbers issue but involves the WD experience base because *the most experienced WDs are selected for upgrade to the SD position.*

Fundamentally, the structure of the crew is non-homogeneous; crew positions can be grouped into different categories (flight -- mission; rated -- non-rated; officer -- enlisted), and each category imposes special considerations on how personnel are managed. Regardless of differences in the positions, all should be managed with equal skill.

## Problem Statement

If AWACS is to be as effective as possible in its mission, it must be properly manned. The goal of the PFT is to achieve this manning,

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quantitatively and qualitatively, in such a manner that the crew force is stable. With the current lack of management tools, AWACS managers have not been able to realistically determine their manning needs. Consequently, the AWACS crew force has been chronically unstable, both in absolute numbers and in the experience base of the personnel constituting the crew force. If AWACS is to be properly manned, the air crew managers require tools to integrate, present, manipulate and analyze information that is pertinent to the personnel acquisition process.

## Objectives

To approach the design of a tool to assist in accurately predict manning acquisition requirements for the PFT effort. To meet this objective, the following sub-objectives must be attained:

1) Establish a "management paradigm" for determining needs that is simple, effective and uniform for all air crew managers, regardless of the idiosyncrasies of the position structure;

2) Identify factors impacting manning level;

3) Identify factors impacting experience level;

4) Identify where appropriate data is located;

5) Determine appropriate models for analyzing the data, and;

6) Provide an adaptive design "road map" so the tool remains viable in changing circumstances.

The following chapters will discuss the methods for accomplishing the above steps, the specific design, conclusions reached during the research effort, and recommendations for further areas of research on this subject.

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# II. METHODOLOGY

## Suitability of a Decision Support System (DSS) Approach

The problem the AWACS managers face in determining personnel requirements is not "well structured". Each manager deals with factors impacting manning that are common to all positions, and with factors unique to his own. Some factors are dynamic, and possibly worse, the importance of factors are also dynamic. Because of the diversity of factors and their dynamic nature, the users of the system to be designed (crew position personnel managers) cannot provide a functional specification of the decision process to be supported. Keen argues that the user's inability to provide a functional specification is one of the hallmarks of a process for which a DSS is appropriate [Keen : 15]. The lack of a functional specification prohibits the use of a purely prescriptive modeling approach; the problem's nature is such that an interactive, semi-structured process is called for.

Current practices in the AWACS personnel requirements process have never emphasized long term effects of the factors managers consider in making their manning decisions. The impact of different factors on short term manning profiles are reasonably well understood by the managers -- in most instances, the short term condition of the force is all that is managed. However, to be effective in stabilizing the crew force, managers must understand the long term impact of their acquisition decisions. They must understand the long term impact of managing crew positions for short term health.

Any system that implements a capability to examine the effects of current management decisions on the future condition of the crew force

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can help the manager understand long term effects of his decisions. In particular, a DSS is an ideal tool in this respect, since it can implement the desired capability in a system that is designed to "facilitate the ... [decision] process rather than to force-fit it into a designer's notion of the best process" [Young : 1]. This allows the user to focus on the problem, further clarifying his understanding of it (possibly gaining new insights), and make decisions. This is a distinct departure from traditional "support systems" where the user is often consumed by the mechanics of the system, to the detriment of process understanding. Traditional systems design is a "builder" driven process; as a result, systems are designed to support the builder, not the user.

A further reason for choosing a DSS approach is the necessarily evolutionary development of the management system. Changes in any system developed will have to be made, since:

1) the importance of factors will change as corrections are made in the force structure, with new factors requiring consideration and some current factors becoming unimportant;

2) the current understanding of factor importance is such that mistakes will be made. The system will need to be modified to adjust for the user's better understanding of his needs; and

3) the use of the system will change the user's decision process from whatever process is first "captured" in the DSS. The DSS will need modification to support new processes its use engenders.
A DSS, oriented around adaptive design, provides a structured framework to evolve the system being developed.

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## Adaptive Design

Adaptive design is a systems design approach where the philosophy is "start small and grow" [Valusek : 105 - 111]. Adaptive design shares the elements of the traditional systems design approach, i.e., requirements analysis, design, development and implementation. However, in contrast to the traditional approach, it does not fix a rigid systems specification before development starts. Recognizing the user usually cannot fully specify the system desired before development starts, the adaptive approach stresses putting a kernel system into the user's hands and evolving it as a result of the user's reactions.

Adaptive design is critical if the decision process being considered is to be effectively supported. Keen provides a succinct graphic that describes why this is so (Figure 3) [Keen : 16]. The three elements in a system design process are the user, builder and the system
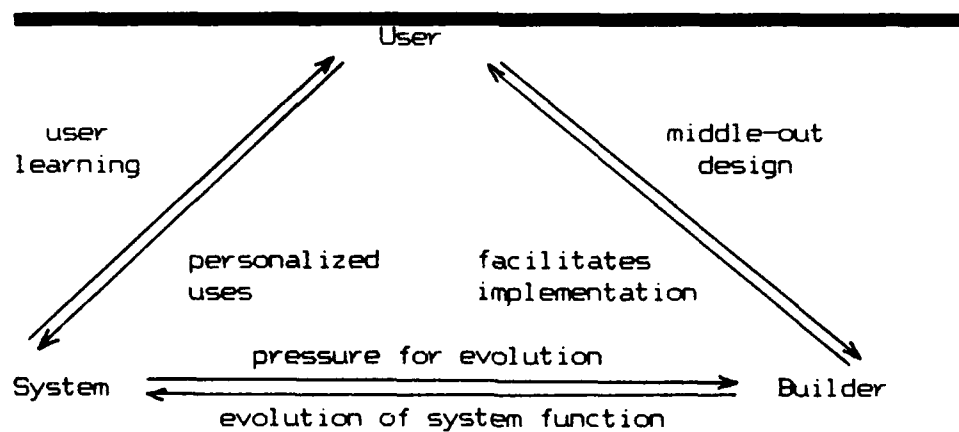


**Figure 3 -- An Adaptive Framework for DSS**

being developed. In design processes to which the DSS approach is suited, there are necessary two way linkages between all three elements.

"A system is a "DSS" only if each ... is relevant to the situation" [Keen : 17].

For the decision process discussed here, all linkages are necessary for the production of a functional system. The System - User linkages are required because the AWACS manning determination process is not well structured. Users will gain insights as the system starts to structure the process; the user will therefore change his use of the system. The User - Builder linkages are required to ensure the proper system is implemented. The middle-out design approach enhances communication by placing a kernel system in the user's hands, providing a design element that can be used by both the user and builder to define the problem. Proper definition of the problem facilitates system implementation. Finally, the System-Builder linkages must exist. The altered use of the system seen in the User-System loop can only progress so far before the system requires adaptation to support the new process. The builder then provides new functions to the system, and the cycle starts over again.

Expanding on the above theme, Ackoff makes the following observation about designing support systems:

> It must be assumed that the system that is being designed will be deficient in many significant ways. Therefore it is necessary to identify the ways in which it may be deficient, to design procedures for detecting its deficiencies, and for correcting the system so as to remove or reduce them. Hence the system should be designed to be flexible and adaptive. ... No completely computerized system can be as flexible and adaptive as can a man-machine system. [Ackoff : 155]

The key points here are  1) that the system must allow for evolution if it is to be effective, and  2) that systems that are designed as man-machine systems are more capable of adaptation than are purely

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mechanical ones.  Adaptive design in the DSS context is highly attuned to both of these factors.  It requires an evolutionary framework for the system *that is part of the system* and can easily allow for the framework in the man-machine interface of the support system.

An adaptive design approach also has "immediate gratification" attributes that make it particularly desirab'e when contrasted to traditional systems development approaches.  Some of these attributes are:

1) Short response times to user inputs.  Where problem understanding is "foggy", extracting the process from the users is a time intensive process.  If the user is to make a time commitment, he must see a return in the short term.

2) User *participation* in the design of *his* system.  The user probably is aware of how foggy the problem is.  If so, he knows mistakes wil! be made.  Providing a system that is responsive to his changing perceptions, many of which will result from the process of defining the problem, allows the user to "get the system he wants" not the one he thought he wanted (or the designer thought he wanted).  The process of watching the system evolve, due to his inputs, assures the user that the system will be what he cesires.

3) User perception that he is being understood.  As a corollary of (2), the communications between the "owner" of a decision process and the builder of the support tool will be poor because of the different realms of expertise.  Mistakes will occur because of poor communication even in problems that are well understood by the user.  According to Cerveny, et al, "the use of the traditional [systems design] approach

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does not adequately address the underlying issue of poor communication between the user and the analyst" [Cerveny, et al : 54]. Adaptive design provides a framework for identifying mis-communications and correcting them. The feedback in the communications process, indicated by evolutionary changes in the system being designed, reassures the user that he is getting what he wants.

The Vehicles of Adaptive Design. Adaptive design, as being researched at the Air Force Institute of Technology (AFIT), above all, provides a means for structuring the development of support systems. For the purposes of this study, three major structuring devices were employed. These devices are concept mapping, storyboarding via ROMC, and the "hook book".

Concept Mapping. The first stage in the adaptive design process is developing some understanding of the decision process being supported. Concept mapping is an educational tool that is adaptable to developing this understanding [Valusek : 107] It provides a medium for identifying elements of the decision process and describing the relations between the elements. With a map of the decision elements, the builder and user can pick an appropriate "initial kernel" (subset) system to be developed. (However, the actual kernel that provides the seed for the system to be developed is usually not fully specified until after storyboarding [described in the next paragraph] is complete).

Storyboarding. After concept mapping, the initial kernel system is described pictorially on paper to ensure that the kernel is what the user actually desires. This pictorial description of the system is called "storyboarding" and was proposed by Andriole as a

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technique for capturing the users views on the important aspects of the decision process being supported [Andriole : 463-469]. Storyboards, in the adaptive design realm, provide the specification of the system to be designed.

The process of storyboarding, with its graphical presentation of the DSS, helps clarify the decision process layout, and usually leads to iterative changes in the initial kernel that is identified for development. At the point where the user is satisfied that the storyboards reflect his desired system, the "final kernel" has been identified. System development then starts, and further adaptation of the kernel can proceed until the desired system is evolved.

**ROMC.** In conjunction with storyboarding, the Representation, Operations, Memory aids and Control (ROMC) structures described by Sprague and Carlson provide a valuable method of ensuring a storyboard design is complete [Sprague, et al : 103-118]. Representations are the presentation of the information the manager requires. The focus is on what form the presentation takes to convey the required information. Operations are the functions executed by the DSS to provide representations. The focus is on how the decision maker's information is produced. Memory aids are the mechanisms required to ensure the user knows where he is and what he has considered in the decision process. The focus is on providing orientations for the decision process. Finally, Control mechanisms are the mechanisms that allow the user to direct the functioning of the DSS. The focus is on facilitating system use. All four of the ROMC factors must be *consciously accounted for* in the design if an implemented system is to

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be functional.

 **The "hook book".**  Finally, the system must have a mechanism to
facilitate adaptation.  A method for identifying new requirements and
system deficiencies, that is readily available *while the system is in
use,* is necessary if the system is to adapt rapidly.  A "hook book",
described by Valusek, provides the necessary mechanism for determining
new systems requirements [Valusek : 109].

The hook book is a software facility embedded in the implemented
system that is accessible from any point in the system.  Fundamentally,
it is an on-line memory aiding facility for capturing user thoughts
about the system (or the decision being supported).  The notes to be
captured are structured (see Figure 4), and have four distinct parts,
these being:

1) the *date* of the note entry;

2) a *label* for the entry;

3) a brief *description* of the idea that prompted the note, and;

4) the *circumstances* that led to the idea.

DATE: _____     LABEL: _____
IDEA: _____
_____
_____
CIRCUMSTANCES: _____
_____
_____

**Figure 4 —** Hook Book Entry Format
Adapted from [Valusek : 109]

Each part serves a specific purpose.  The date allows
chronological sorting of ideas, the label allows sorting of ideas by

system function, the description provides the basic memory aid as to
what the user wants, and the circumstances provide the key to "detailed
recall of the [user's] idea during requirements elicitation" [Valusek :
109]. Together, the four parts of the hook book are sufficient for the
orderly identification of new system requirements, and ensures the
system can evolve and remain useful.

These three "vehicles" together are the mechanism through which an
adaptive design approach can be implemented. They ensure a systems
design environment that fosters ready communication and rapid
implementation of unambiguously communicated desires (user's) and
intentions (builder's).

## Establishing a "Paradigm"

To design a proper paradigm, it is necessary that there be a clear
understanding of who the users are, and what their areas of expertise
(and limitations) are. If users are properly identified, a paradigm
that provides "procedures and data representations that fit well with
specific managers' established activities" can be designed [Meador, et
al : 162]. This is important if the DSS is to be accepted. A support
system that presents a non-technical manager with statistical summaries
to guide his decision process is an effective way of ensuring the system
is not used. Likewise, providing a system that 1) allows the manager to
view data pertaining to his problem (even at some level of aggregation
and in various formats), without 2) providing a method of synthesizing
its impact on the decision, is an exercise in Management Information
Systems (MIS), not DSS. The above MIS type systems are designed under
what Ackoff calls the "give them more" syndrome, which causes managers

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to "suffer ... from an *over abundance of irrelevant information* [Ackoff
: 147]. A proper management paradigm will make a management system
easily used; a poor paradigm will condemn the system to oblivion because
it requires too much of the user.

Establishing a proper paradigm rests on the identification of
users. For this study, the users to be supported and their "general
characteristics" are readily definable because of the 28 AD air crew
management structure; identification is basically a matter of
observation to be detailed in the following chapter.

## Factor Identification

Many of the factors that bear on this problem were identified in a
previous research effort in this area [Schneider]. Some were addressed
adequately, some need more detailing before they can be useful in an
implemented system. The factors that received the most attention in the
previous research effort were those that dealt with manning level.
While the issue of experience level was raised, methods for determining
these levels were treated scantily. Identification of measures of
experience and methods for profiling the experience base of the crew
force were not adequate to guide a decision process attempting to
stabilize experience in the crew force.

The factors were identified in discussion with air crew managers
and analysts at the 28 AD during the course of multiple PFT conferences.
In most cases, the 28 AD PFT participants indicated that they were able
to identify factors that were important to them, and that they attempted

to estimate their levels and impact on the AWACS crew force in making PFT recommendations. They also indicated that many of the estimates were indefensible, as they were generally "best guesses".

**Manning Level Factors.** For the purposes of this research, the factors previously identified as drivers of manning level were accepted for the kernel design. Phone interviews with AWACS managers verified no significant changes in the set of perceived factors have occurred [Guzec]. These factors are related to two primary areas: 1) personnel losses from the system and 2) changing authorizations.

The personnel loss factors are derived from historical databases and are: 1) the time spent in the Air Force, and 2) average "tour" length. The first factor indicates the losses AWACS will suffer due to separations (end of enlistment, retirement, etc). The second factor indicates the losses due to Permanent Change of Station (PCS) out of the AWACS community.

The factors that bear on authorizations for each crew position were discussed briefly in chapter one. They are PAA, crews per PAA, staff authorizations, and number of personnel per crew. These factors are set outside of the PFT process, being part of overall Air Force structuring policy. As such, they are planned well in advance of any PFT planning on which they bear and are matters of record.

In this study, none of the above factors will be addressed from the perspective of why they occur. Rather, they will be used solely for the purpose of predicting manning shortfalls. The issue of (for example) why some mid-career flyers choose to separate before retirement is not examined. The fact that some percent historically do separate

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is not examined. The fact that some percent historically do separate early is, however, of use in predicting acquisition needs.

**Experience Level Factors.** Estimating the experience level of a crew position entails identifying the factors that can describe experience, building a model to estimate the individual crew member's experience (as a "score"), and then using the estimated score to profile the experience of the position. This profiling can be done in any number of ways, e.g., it can be described in terms of mean experience, median experience, or via a graphical presentation of the experience distribution. This process is depicted graphically in Figure 5.

Unfortunately, experience level quantification is difficult to accomplish for most of the mission crew positions. This is because no direct measures for assessing experience of the individual crew members exist. Estimates of individual experience must be based on surrogate measures, where the choice and significance of these measures are unclear.

The first step in assessing the experience of a crew position is determining what surrogate measures are useful in developing "experience scores" for the individual crew members and then developing the scores. Examples of possible surrogate measures are: rank, years of service, Standardization Evaluation (StanEval) ratings, number of flying hours, number of missions flown, number of exercise missions flown, etc. Since appropriate surrogate are uncertain and the number of possible surrogates needed to produce an "experience score" may be large, any method used to identify factors and produce scores will have to be capable of identifying and aggregating multiple factors in the face of

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user uncertainty.   Two possible methods that can identify the necessary

factors and directly aggregate them into usable scores are considered.
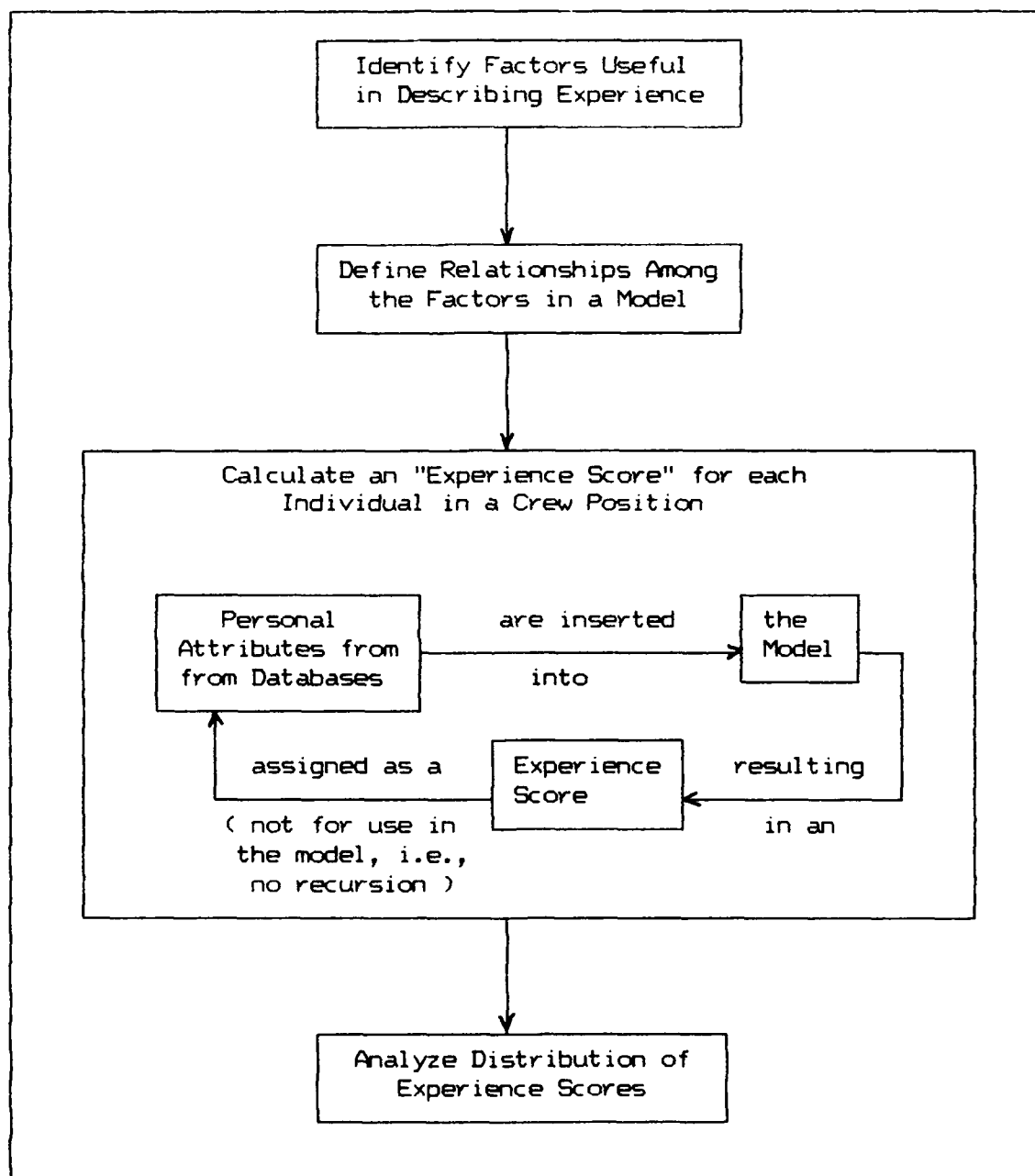


**Figure 5** — Experience Profiling Processs

These are 1) Multi-Attribute Decision Analysis (MADA), and 2)

regression.   These methods are discussed below.

**MADA Methods.**  Estimating experience for the crew members can be
approached from the perspective of "expert judgement".  There are
experts in the AWACS community who are familiar with the jobs each crew
member performs and who routinely make mission decisions based on their
estimates of who is most capable.  If an expert judgement approach is
used, the issue becomes one of eliciting from the expert the uncertain
factors that enter his decisions, their relative weights, and the trade-
offs (utility) within them.  Multi-Attribute Decision Analysis is an
analysis discipline geared to structuring problems such as this, where
decisions (answers) are plagued by uncertainty [SmartEdge Documentation
: B-2].

To elicit a set of possible factors from the experts, surveys are
used.  The intent of the surveys is to establish ranking among the
possible factors (to reduce the set of possible factors to manageable
proportions), to establish that the expert being surveyed is consistent,
and to look for possible factors that have not been considered.  Two of
the standard surveying methodologies for developing measures on 1) the
ranking of factors and 2) respondent (and factor) consistency are based
on semantic scales and pair comparison, respectively [Chan].
Solicitation of new factors to be considered can be achieved through
simple questionnaires.

Appropriate relative weights for the factors and the utility
function that describes the relationship of the states within each
factor can be determined through a series of reference lotteries.  In a
"basic" reference gamble procedure, sequences of reference gambles are
conducted where, prior to the gamble, payoffs for the reference gamble

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are established. Then, iteratively, probabilities ($p$) for winning the gamble are assigned, and the certainty equivalent ($CE$) for the gamble evaluated (where the CE is the point where the expert being consulted indicates he is indifferent to the lottery and the certain value). Plotting $p$ verses $CE$ yields the utility curve for the factor being examined [Holloway : 422].

Modifications of the basic reference are available. Holloway suggests that the 50-50 is often the best gamble, since people often think in terms of go-no go choices [Holloway : 428]. Here, $CE$s are first determined for $p = 0$, .5, and 1. For the rest of the procedure, $p$ is fixed at .5 and the $CE$s for each gamble elicited. The probability for the certain value can be determined from the gamble conducted.

The lotteries described above are conducted in a structured question and answer session, where the expert indicates his preferences to the series of proposed gambles. This lottery structure elicits both the factor weights and the utility functions that underlie the expert's estimations. Combination of the weights and utilities in an additive formulation produces a "score" for individual crew members when the formula is evaluated using the crew member's attributes for each factor. (Reasonably easy to use commercial software packages that conduct these types of question and answer session exist, e.g., SmartEdge, ver (3)).

**Regression Methods.** Two classes of regression treatments suggest themselves as candidates for determining appropriate factors for constructing an experience score. Both require that the crew force be "categorized" in some manner prior to regressing to identify factors. The "categories" are then used as the response to be fit by a regression

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of personnel data. The set of regressors that are significant are the factors to be used for producing experience scores.

**Logistic Regression.** Typically this type of regression falls into the "logistic regression" arena. In cases where the response variable is categorical, "theoretical and empirical considerations suggest ... the shape of the response function will frequently be curvilinear [Neter, et al : 361]. Logistic transformations of the response function produce responses of appropriate shape and have the desirable property of being asymptotic to the extreme values of the response, i.e., predicted values produced using the logistic response function will not fall outside of the range of the categories of the original response [Neter, et al : 356-363].

**Multiple Regression with a Binary Response.** If the initial categorization of the crew force is restricted to two groupings, (i.e., split the personnel into an "expert group" and a "less than expert group"), the response is a binary response. In this case, a multiple regression is feasible [Neter, et al; 354-361]. As in all regression, the factors to be used are those that test significant in predicting the responses.

The methods discussed above for determining appropriate experience factors and producing experience scores are only some of the possible methods for dealing with the problem at hand. Certainly, they do not constitute the entire spectrum of options. Each has problems associated with its use. In some cases, the problems are inherent in the method itself (regression using binary categorical responses). In others, the problems encountered in using a particular method are related to the

environment in which the method will be applied (both MADA and logistic regression share this feature).

In the following chapters, which deal with design and implementation of the DSS, the particular problems with each method is discussed, and a choice of method for the kernel design is selected and explained.

# III. Overall System Design

## General

Designing for adaptation is critical for the decisions being
supported by this research effort. The decisions to be made go beyond
what has been attempted by AWACS air crew managers in the past,
explicitly addressing experience level inventories and the need to
stabilize both manning levels and experience levels in the various AWACS
crew positions. Since the decisions being supported cannot follow an
already established decision process, an initial process must be
established and then adapted as the users determine exactly what is
required to fully support their decisions.

The necessity for supporting system adaptation is also inherent in
the goals of the decisions being supported. The goals of stabilizing
manning and experience in the AWACS crew positions are geared to change.
Since the system will be changing the environment it addresses, it must
also change to continue to address the environment of interest and
successfully achieve its goals.

The specific design of the DSS examined in this research effort is
driven by two major concerns: conceptual design considerations that are
related to information requirements and technical considerations that
deal with how the system is implemented. Both of these "design
elements" must be addressed in the adaptive design environment. The
conceptual aspects of the design effort deal with determining user
requirements, identifying a decision process to support the
requirements, and establishing the infrastructure necessary to support
the system's evolution. The technical design considerations deal with

providing the environment where the decision process occurs.

The above delineation of design concerns is made only to indicate
that there are two dimensions to the design problem, not to imply that
the design issues can be treated separately. One (the conceptual
portion) is primarily the realm of the user and designer, while the
other (the technical portion) is primarily the realm of the builder.
However, there is not a clean division in these two efforts. For
example, the act of specifying that the system be able to adapt has an
impact on the technical portion of the design effort, and requires
choosing specific facilities to ensure the necessary adaptations to the
system are supported.

The following sections of this chapter will discuss each of these
design areas. While the areas are not cleanly divided in practice, the
discussion of each area will be separated for clarity.

## Conceptual Design Considerations

The conceptual design issues that need to be considered in
developing a DSS can best be addressed from the context of two elements
of the adaptive design process. These elements are the information
requirements determinations (IRD) phase and the information requirements
analysis (IRA) phase. During the "earlier" IRD phase, user requirements
are expressed as general lists of possible requirements. These
"candidate" requirements are subjected to scrutiny during the IRA phase.
It is here that the actual "succinct" list of requirements defining the
system's form is generated. Each of these phases are distinct in their
goals. However, a common set of design "tools" can be used for each,
and are those that were discussed under the methodology of adaptive

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design.

The conceptual design issues in this research were addressed in four distinct phases. These are: 1) concept mapping, 2) storyboarding, 3) kernel selection, and 4) establishment of a paper hook book to capture the road map for future development of the system. These four phases are discussed below.

**Concept Mapping.** Initially, a concept map was constructed to describe the elements of the problem and their interactions. The concept map was generated by this researcher and another former 28 Air Division analyst [Sumner]. (In this instance, these analysts acted as proxies for the actual decision makers to be supported). Both participants in the concept map's generation have had experience with the AWACS PFT cycle, and have participated in AWACS PFT conferences in advisory capacities.

An aggregated concept map for the acquisition problem is shown in Figure 6. Relationships among the major elements are easily seen in this high level presentation.

The detailed concept map for the overall acquisition problem is included in Appendix A. The map is by no means complete; its function is to delineate the problem space sufficiently to allow the design process to continue with some assurance that the problem's total scope has been considered.

**Storyboarding.** Storyboard production for this system occurred in three cycles. The initial storyboards for the system discussed here were conceptualized at the 28th Air Division in mid-1987 in response to dissatisfaction with aspects of the storyboards produced by Schneider

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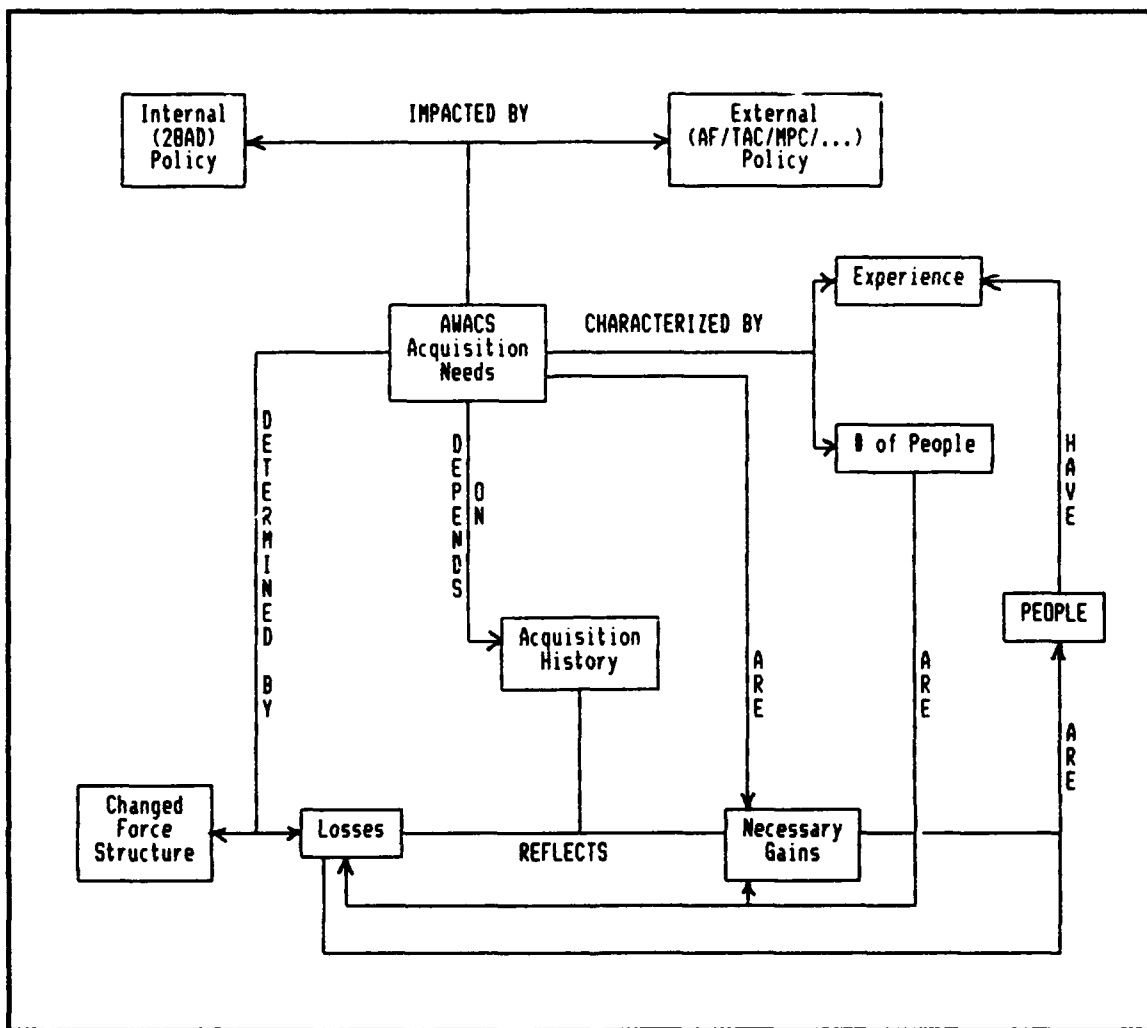
**Figure 6** - High Level Concept Map of Acquisition Problem

[Schneider]. This early definition of the desired system occurred
during brainstorming sessions among the 28th Air Division analysts (Capt
Geo. Mark Waltensperger, and Lts Kevin M. Holt and David L. Sumner).

The evolution of the storyboards continued at AFIT when Holt and
Sumner were formally exposed to DSSs and storyboarding. Here, the AWACS
PFT problem was used as a vehicle to better understand the structures
and goals of storyboarding. In the process of developing an
understanding of storyboarding, a system that would support 28 AD
personnel acquisition was captured in a "complete" set of storyboards.

Finally, the process of this research led to modifications of the storyboards as the problem was addressed in more detail. The final storyboards were evaluated by Sumner, acting as a proxy decision maker, to ensure that they continued to define the form of the desired system and to ensure that the system addressed "all" of the user's decision support needs. Three of the storyboards are shown below, and the RQMC (as discussed in chapter 2) of each is detailed. The complete set of "final" storyboards are included as Appendix B.

**Representative Storyboards.** Figure 7 is the home display for the system when it is first entered. (As such, it is also the kernel of the DSS, which is discussed in detail in the next chapter). The user enters the system to a display that graphically *represents* the current experience profile of the crew force he manages.

Here, the state of the crew position is shown by the distribution portrayed in histograms. The left histogram indicates the impact of known losses (i.e., known retirements, known PCSs, etc.) on the position's experience while the right indicates a best case for experience based on recapturing all known "eligible" ex-AWACS personnel in the Air Force manning pool. (The top portion of the stacked bars indicate experience contributions by members being lost or potentially recaptured).

*Operations* are minimal for this screen. At the decision command level (top menu), the user has the option of changing the crew position being profiled and of selecting different manning profiles. At the systems support command level (bottom menu), he can select any option.

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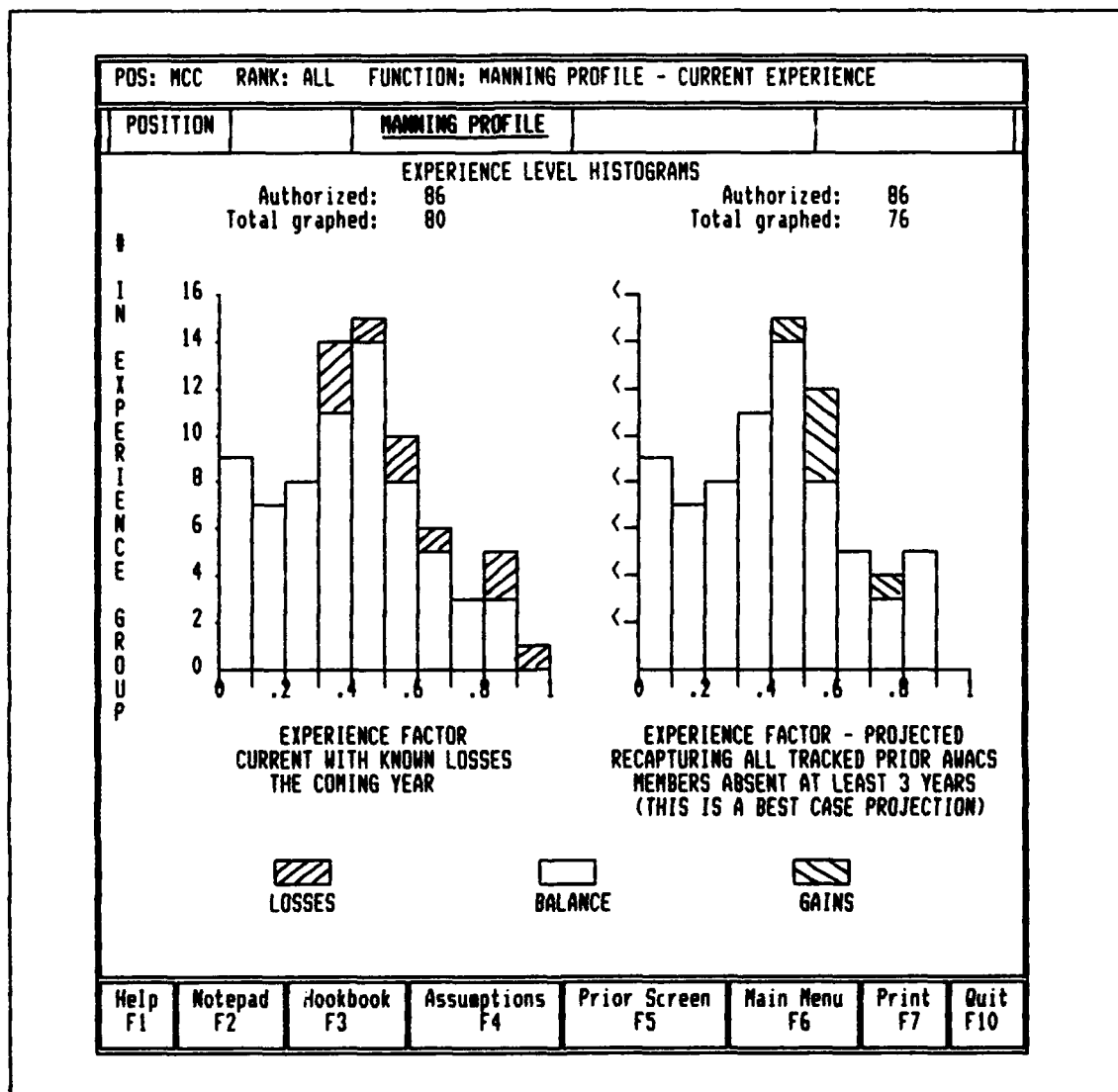
**Figure 7 - Home Representation of the DSS**

*Memory aids* are embodied in three separate areas of the screen. First, the top line of the screen indicates to the user specifically what he is looking at. Second, the command bar has the applicable command that generates the representation highlighted (and also indicates decision commands that can be executed during the current operation, i.e., change the crew position to be examined). Last, the coding of the bar segments is documented below the histograms.

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Finally, the *control* mechanism of the system is embodied in the command selection procedures and options available to the user. In this instance, the user can select any of the system support options from the bottom command bar (and these commands are purposely separated from the commands that bear on the decision process), or he can examine other manning profiles that are of interest to him.

Figure 8 is the display where, ultimately, the final decision is made about which acquisition strategy is best. Manning AWACS is not an
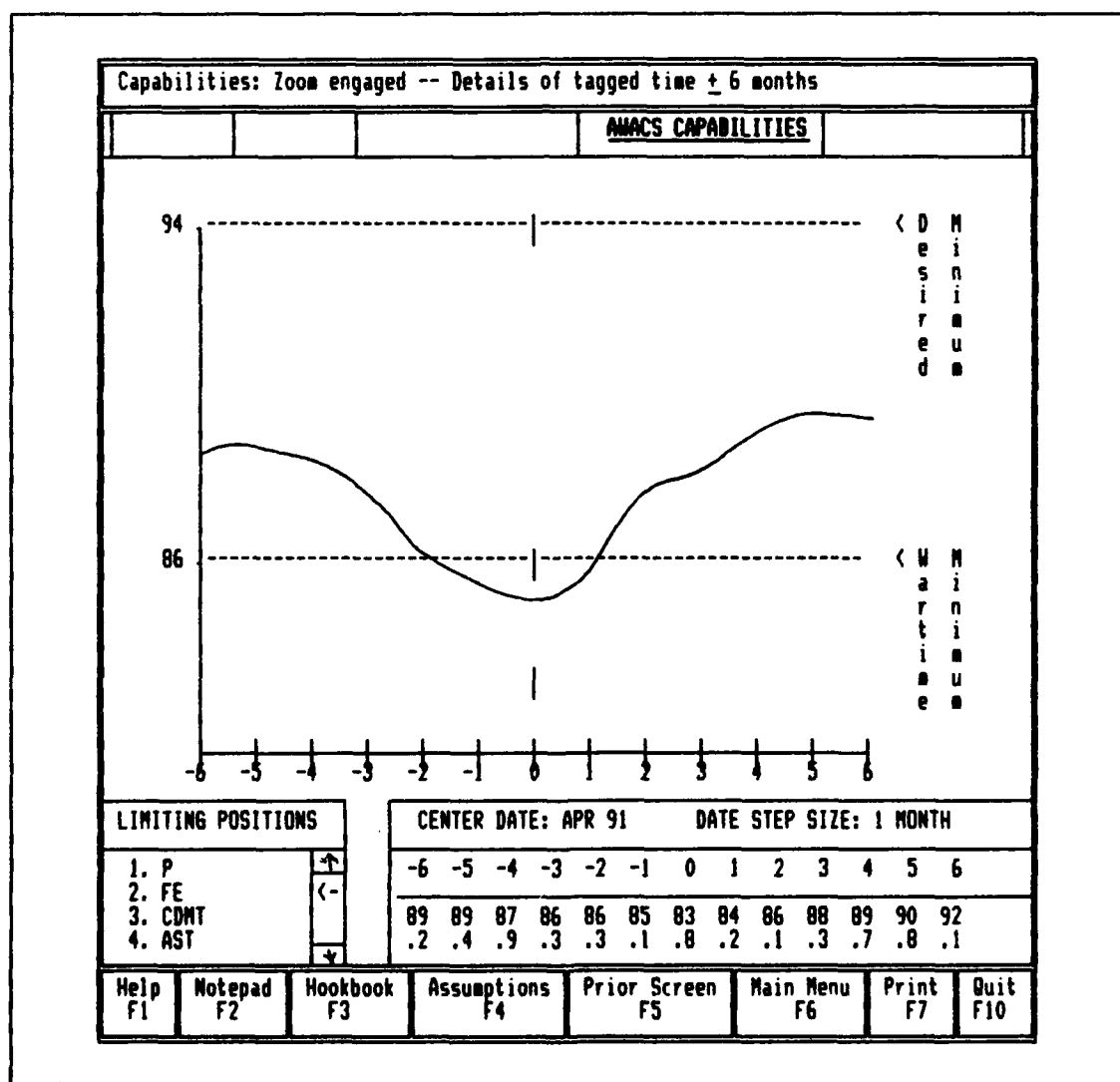


Figure 8 - Capabilities Representation of the DSS

end to itself; a mission effective AWAC capability is the goal, and this goal is why manning acquisition is an issue.

For each of the acquisition strategies the manager considers, he can examine the manning consequences on AWACS mission capabilities. Capabilities information is *represented* three ways: graphically by a line that is plotted relative to reference values, numerically at a detailed level in a table below the graph, and, finally, in a table that shows crew positions in the order in which they limit capabilities the most.

*Operations* include the ability to "zoom" to each crew position to examine its specific impact on capabilities and accessing system support functions such as getting printouts of the representation or capturing thoughts in the hookbook or notepad. ("Zooming" is accomplished by selecting the appropriate number from the capabilities limitation list). *Memory aids* and *control* mechanisms are largely the same as those discussed in Figure 7.

Figure 9 is the storyboard for the DSS function of keeping the user abreast of scheduled changes in the manning structure of the AWACS. It is a tabularly oriented *representation* of the changes in the four factors that cause manning requirements at the systems level. The user is shown the current values for each of the factors in the BASE column, and is shown when and by how much (relative to the current values) changes in factors will impact each crew position.

*Operations* are restricted to causing the crew positions and their relevant information to scroll in their windows and to accessing system

|        | 1989    | 1991      | 1996 | 2000 |      | BASE |
|--------|---------|-----------|------|------|------|------|
| PAA    |         |           |      | +3   |      | 29   |
| CREWS  |         |           | +.2  | +.2  |      | 1.7  |
| POS    | AIRCRAFT MODIFICATIONS | | | | | |

|      |   | 30 -- 35 |   |   |   |   |
|------|---|----------|---|---|---|---|
| SD   |   |          |   |   |   | 1 |
| WD   |   | +1       |   |   |   | 3 |
| ASO  |   | +2       |   |   |   | 1 |
| AST  |   |          |   |   |   | 2 |
| ART  |   | +2       |   |   |   | 2 |
| CDMT |   |          |   |   |   | 1 |
| CSO  |   | +1       |   |   |   | 1 |
| CT   |   |          |   |   |   | 1 |

| POS | ORGANIZATIONAL CHANGES | | | | | |
|-----|---|---|---|---|---|---|

|      | ADD 962 |   |   |   |   |    |
|------|---------|---|---|---|---|----|
| P    | +2      |   |   |   |   | 18 |
| NAV  | +1      |   |   |   |   | 14 |
| FE   | +1      |   |   |   |   | 3  |
| MCC  | +1      |   |   |   |   | 28 |
| SD   |         |   |   |   |   | 9  |
| WD   |         |   |   |   |   | 8  |
| ASO  |         |   |   |   |   | 23 |

| Help | Notepad | Hookbook | Assumptions | Prior Screen | Main Menu | Print | Quit |
|------|---------|----------|-------------|--------------|-----------|-------|------|
| F1   | F2      | F3       | F4          | F5           | F6        | F7    | F10  |
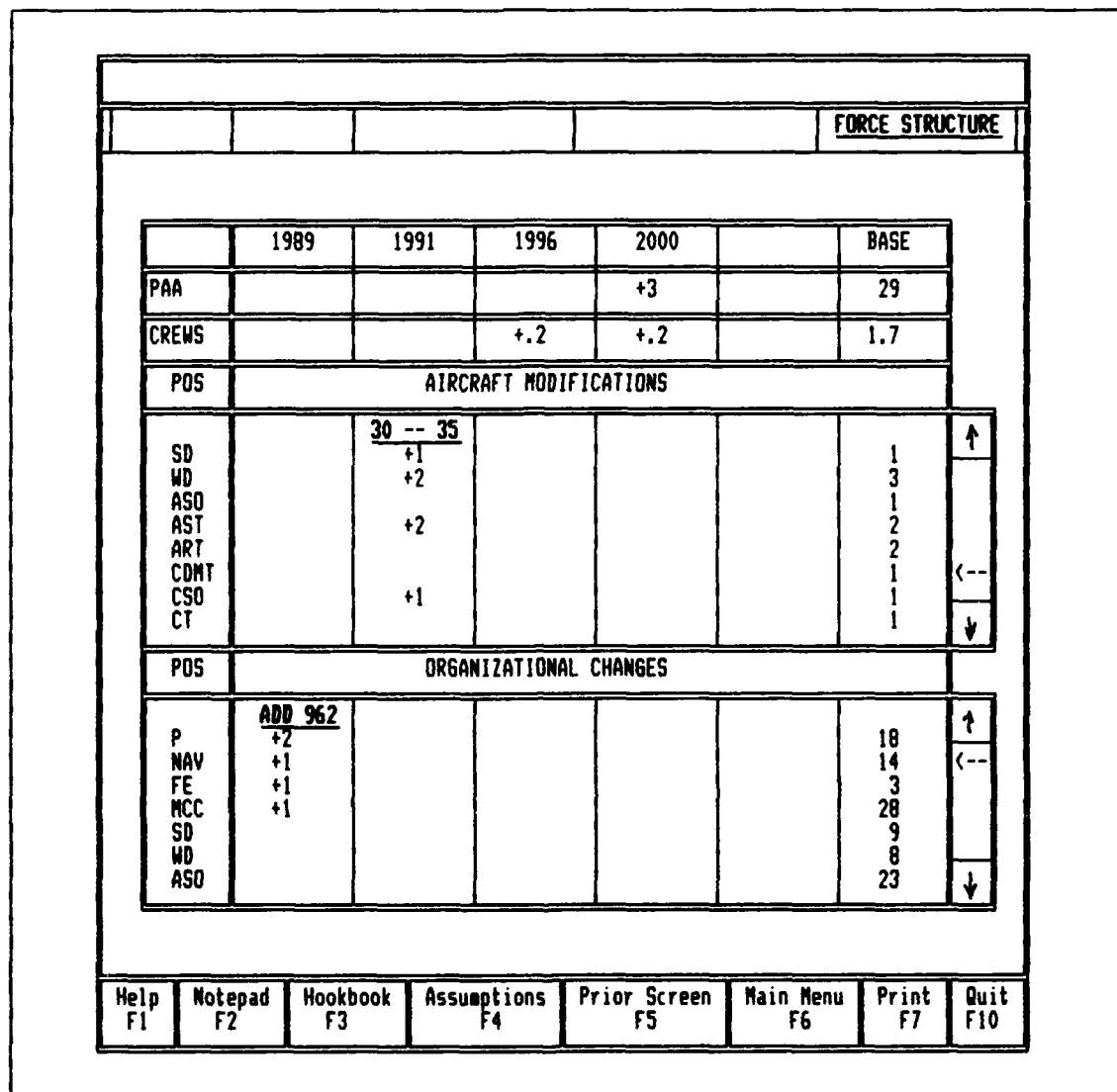
**Figure 9** - Force Structure Representation of the DSS

and decision commands. *Memory aids* and *control* mechanisms remain the same as in figure 7.

These three storyboards are representation oriented, having minimal operations input from the user. A heavily operations oriented figure is discussed later in this chapter.

**Storyboarding Contributions to Understanding System Needs.** As indicated in the previous chapter, both the concept map and storyboards

impact the selection of the kernel system to be developed. The
storyboard process immediately reinforced this fact. This process
reduced the scope of what was addressed to a small portion of the
concept map, choosing not to directly address why perturbations (from
desired stable conditions) of AWACS manning occurred, but rather
focusing on how to correct perturbations when they occur. The
storyboards focus on a system that allows managers to identify manning
deficiencies, examine means of correcting the deficiencies, and portrays
the consequences on manning structure of whatever acquisition decisions
are made.

It was also during the process of storyboarding that the issue of
exactly "who" the users being supported were was addressed in detail.
Until this point, the problem was looked at largely from the perspective
of stabilizing the crew force *in a prescriptive manner*, not from the
perspective of a decision process. User needs and impact on the system
had not been considered. The specific characteristics of the users were
addressed at this point, and the "shape" of the DSS that could support
them determined. Consequently, storyboarding was critical to guiding
the formulation of the decision process to be implemented in the initial
system and the paradigm through which the decision cycle would be
expressed. The issues of decision process and paradigm are discussed
next.

**The Decision Process.** As stated above, this system
addresses areas in AWACS crew management not addressed previously.
Lacking a process to model, an initial process to support the user's

decisions had to be developed. This decision process could then be modified (or totally new processes implemented so that the problem can be addressed multiple ways) as the users determined new needs (or desires) for support in addressing personnel acquisition decisions.

The issue of supporting particular decision processes is widely discussed in the DSS literature. It is generally held that, to provide effective support, a DSS must not constrain decision makers to any one view of how to approach a decision. The user should be allowed to establish his own "best" way to address the problem being supported [Robey, et al; Cohen]. In the initial stages of the design of this DSS, however, some process, not necessarily the "best", was required as a starting point from which growth and adaptation could proceed. A decision process was therefore established.

The basic decision cycle established by the storyboards is to identify the current state of the crew position with respect to experience and manning level, and then proceed to a "what-if" cycle to examine various decision alternatives. During the "what-if" cycle, a manager can assess multiple strategies for correcting crew deficiencies based on a clear understanding of the crew's current state. Support is also provided for direct examination of the personnel databases and for examining scheduled changes in the AWACS force structure that will alter the manning state.

**The Decision Paradigm.** Typically, the managers to be supported by the proposed DSS are senior crew members assigned to a Tinker AFB AWACS unit. Uniformly, the managers assume the job of

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managing their respective crew positions as a duty in addition to their
normal flying responsibilities. To support these managers effectively,
system design must occur with the understanding that crew management is
only one facet of the managers job, and not necessarily the most
important (in the managers eyes). *First-and-foremost, it must be
recognized that the managers are crew members, not personnel
specialists.*

The management paradigm for this system must reflect the user's
capabilities and allow him to make decisions without being burdened by
the system. A proper management paradigm makes the management system
easily used; a poor paradigm will condemn the system to oblivion because
it requires too much of the manager.

To ensure the system is useful to the identified user, a simple
graphical paradigm was adopted. The estimated state of the crew
position is depicted as a line that can be compared to a line
representing the desired crew state. (It is possible that as managers
become familiar with the system and gain expertise in making decisions
with its aid, they may find statistical summaries useful, particularly
when trying to defend their need estimates to higher headquarters. This
can be added to the design at a later date. Initially, however, the
system should be limited to graphical portrayals of decision results.
These are easily understood and tend to limit the manager's sense of
information overload).

In Figure 10, the dashed line represents the desired manning level
for the crew position, and is specified by authorization levels mandated

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by force structure considerations (show in Figure 9). The solid line is
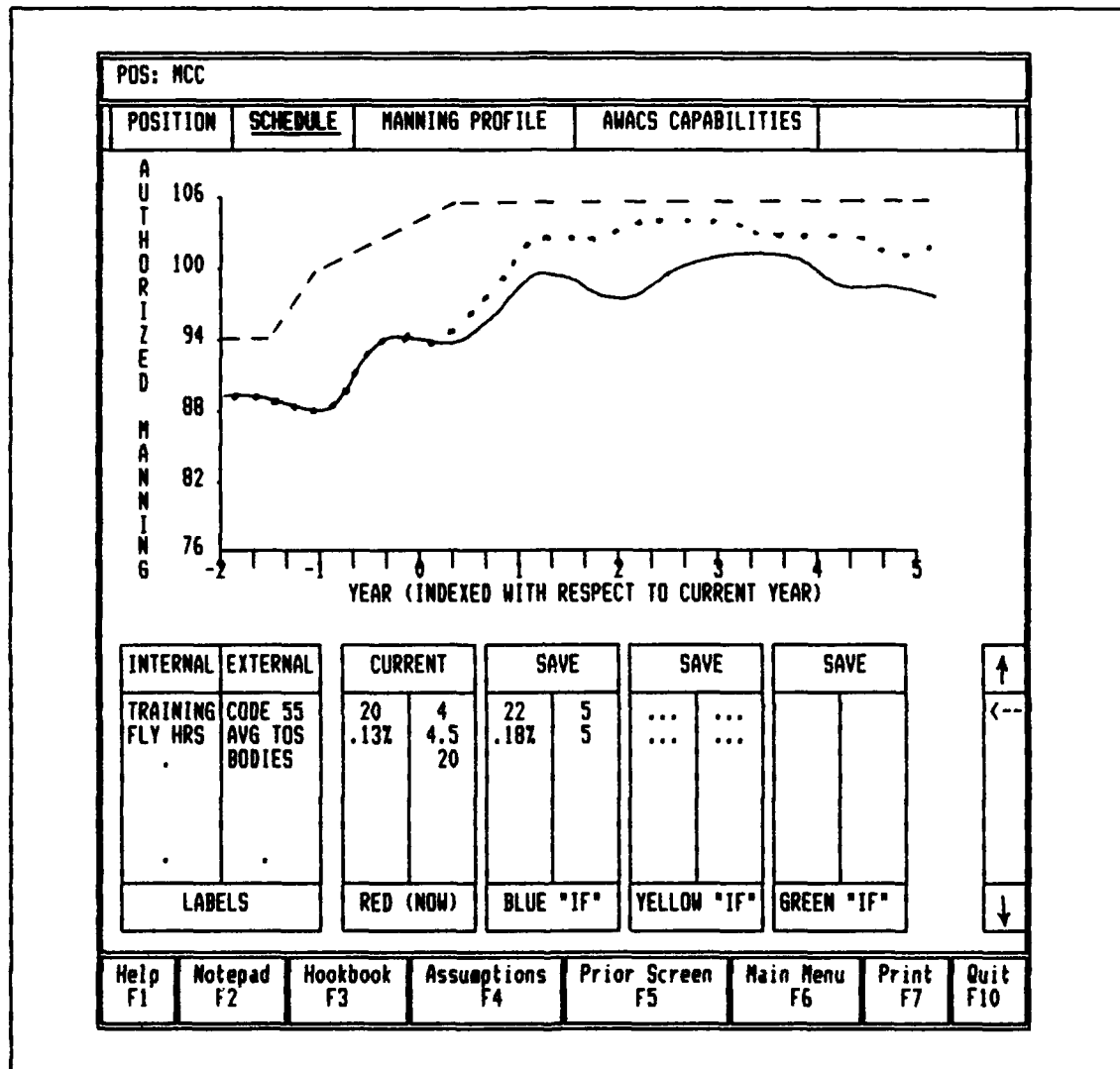


Figure 10 - Scheduling Representation of the DSS

the projected manning level based on current acquisition decision

parameters. The manager's objective is to make the solid line match the

dashed line by suitable choice of values for the acquisition decision

parameters. The manning level projections that arise due to the manager

changing parameters are graphed as the dotted line, and can be compared

to the desired levels and to the levels that result from current

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parameter settings. (Relative to the previously discussed storyboards, this screen is where the user's major *operations* occur. He can change multiple parameter values, and save intermediate combinations of settings for comparison of the results of his various "what-if" examinations of acquisition possibilities).

**Kernel Selection.** While the concept map addresses the overall problem space and the storyboards restrict the space to a subset the users want supported, the overall system specified is still a major undertaking. To attempt to give the users a tool that allows them to start addressing their problem, it was decided that an appropriate kernel would be the capability to assess current experience in the various crew positions. The kernel's selection and development is discussed fully in the next chapter.

**Continued Adaptation.** The mechanisms for fostering continued system adaptation are embodied in two capabilities included in the system. These are the hook book discussed previously, and an explicit assumption review capability triggered by the "ASSUMPTIONS" button described in the storyboards.

The hook book was started in a paper form at the beginning of the design process to capture needs for system evolution. (These hook book entries are included in Appendix C). This was important to the system's development in that it captured evolutionary needs without squandering design resources on redefinition of the problem. In other words, it allowed kernel development to continue, rather than causing the kernel to be continually redefined. In its system's integrated form, the hook

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book serves the same function, allowing the user to capture needs without unduly interrupting the decision cycle in which he is engaged.

The explicit inclusion of an "ASSUMPTION" button was modeled after that described by El Sherif, et. al, in their discussions of support systems developed for the Egyptian cabinet [El Sherif, et. al. : 560]. It was included as an adaptive design mechanism because it forces the user into an awareness that decision making depends on more than the data that is manipulated. How and why the data are manipulated, and the meaning of the results can be very assumption sensitive. If the system is to adapt successfully, any assumptions that are inherent in the system's implementation must be open to scrutiny and change.

Having discussed the adaptive design elements of this research, the remainder of this chapter is devoted to a discussion of the technical design considerations of the DSS considered in this research.

## Technical Design Considerations

The technical design considerations for this effort are as extensive as those of adaptive design, and are equally as important. Technical elements of a system's design can relegate a conceptually elegant system to a less-than-sterling system when implemented, with incorrect selection of technical design components hindering system development and use. Technical design considerations include:

1) choosing the particular hardware and software environment to be used;

2) identifying and planning access to data necessary to support the decision process;

3) identifying places in the decision process where models are

necessary (or desirable) to support decisions, and

4) choosing appropriate model formulations and managing the "model base".

**Environment.** Choosing the hardware environment to be used was a non-issue for this DSS. The 28 Air Division has invested heavily in Zenith Z-248s, with networking of the systems in a beginning stage. All air crew managers have ready access to these machines.

The software environment is not as clear cut, other than the requirement that the software run on Z-248 computers. Ideally, a DSS generator would be employed to design and implement the desired system. However, this option was not examined for two reasons. First, procurement of the software in time for use in this effort presented problems. Second, it was beyond the scope of this effort to even identify an effective DSS generator (if it existed) that could support the requirements embodied in the storyboards. (In another Air Force DSS development effort, two years were spent evaluating numerous software packages "claiming" to be DSS generators [Walker, et al]. A large number of candidates were examined, and more than half were eliminated from the evaluation process, *because they were clearly not DSS generators, regardless of the vendor's claims*).

Another environment rejected for the implementation of this DSS was examined in the previous research effort in this area. Schneider examined the feasibility of using an off-the-shelf software package, "ENABLE", as the environment for generating a DSS. The windowing abilities and the integrated database, spreadsheet, graphics and word processing features in this package were exercised extensively in

developing a prototype DSS, and "ENABLE" was found adequate to produce a workable DSS.

From the user's perspective, however, this environment had severe shortcomings that would preclude its use as the environment of final implementation. The test system that was demonstrated at the 28 AD was driven with small test databases and simplified models. It was, none-the-less, incredibly slow, which aggravated the operators, and it was uncomfortable to operate because of the way "ENABLE" transitions between its various "integrated" modules (i.e., screen bounce and flash, and "ENABLE" environment menus flickering past as the package made transitions).

In general, the man machine interface can be a major factor in a system's success, and speed is a major component of this interface. Slow systems are perceived as being "unresponsive" to the user, and are therefore avoided. For "ENABLE" (and probably any integrated "office" software), speed was a compound issue. In the integrated environment, trade-offs are made in the capabilities of the various modules, with no module being the equal of the best stand-alone packages that are available to perform the same function. Further, the very fact of having an integrated environment in a general package entails overhead to exercise all of the package's abilities, *including those that are not needed* for a particular application (say, a DSS). This is probably the case for any general purpose system; they will always have overhead to support requirements not necessary for a DSS, and the DSS suffers.

For the reasons alluded to above, the final environment for

implementing the DSS examined here should be provided by a stand-alone program that provides the user interface prescribed by the storyboards, which executes all of the desired functions, and which supports other functions only as their needs are identified during the adaptive design process. Unfortunately, this has undesirable consequences for systems adaptations. These consequences are discussed in Chapter 5.

**Data.** The data to support this DSS is available at the 28 AD. However, it is not in a form that can be directly used by any automated system. (A large part of the data is in word processing documents that are updated daily).

An AWACS wide, standardized database for crew management functions that contains most of the necessary data has been designed using DBASE III. When it is in place, implementation of this DSS can begin. The other necessary data elements that are not part of the above database can be incorporated into a small database, or are on base level computers from which they can periodically be down-loaded in Z-248 readable formats and converted to DBASE III file formats for use in the DSS. (The necessary data elements and their sources are included in Appendix D).

**Models.** This DSS requires three major model types to synthesize personnel data and drive the displays providing the decision testing mechanism. First, models to project losses in each crew position are necessary. These models will be used to provide the loss estimates to a simple additive model that drives the manning level displays, and will also feed the models driving the experience profile displays. (These

are the displays shown in Figures 10 and 7 respectively). Since these models tie into experience level projections, they will necessarily be complex. They will have to project losses in distinct categories in each crew position, where the categories are defined by a personnel factor that is important in estimating experience.

Second, models for each crew position that assign "experience scores" to the members of the crew position are needed. These scores will provide the data used to profile the experience in the position. (These scores are aggregated to produce the histograms shown in Figure 7).

Finally, a model that evaluates AWACS mission capability as a function of manning and experience levels is required. (This is the model that drives the display shown in Figure 9).

Each of these models will require extensive management in that they require continual updating until such time as the crew positions they address become stable (and periodic examination there after). Model management will entail AWACS analysts periodically rebuilding the models. Model accuracy will change as factors pertinent to the model's function change, due to outside forces (e.g., force reduction that remove classes of people in an unexpected manner), or due to actions resulting from the use of the DSS that alter the force structure.

The models that drive the system are the major "repository" of assumptions that the system functions under. Therefore, in addition to updating the models, the analysts have a critical responsibility to document the changes in assumptions that are inherent in changing the

models.  (As stated previously, review of assumptions is critical if the system is to remain useful).  More information on models can be found in Appendix E.

Having discussed the overall system design, the following chapter deals with the design of the kernel DSS.

# IV. Kernel Design

## General

The overall system discussed in the previous chapter will entail a large and time consuming effort to implement in its entirety. Therefore, some portion of the system needed to be addressed in detail to: 1) demonstrate to the user that progress was being made, 2) to help the user solve some portion of his problem, and 3) to put an initial tool into the user's hands so that the tool's use would help the user refine his perceptions of his needs. To get the system up and running, a kernel was selected that provides managers an initial capability in assessing acquisition needs where they currently had none.

## Kernel Selection

Managers currently deal with acquisition planning solely from a short term "numbers" perspective. They plan personnel acquisitions to correct any shortfall from authorized manning levels that they see arising over the near term life of the crew force. Even though acquisitions are managed to correct short falls in manning level, there is a widespread recognition in the AWACS community that experience in the crew force should also be managed.

Because of the difficulties in determining experience, experience profiles of the crew positions have been measured against arbitrarily specified references, (i.e., all WDs having one year's flying experience are "experienced" and all CTs with 600 E-3 hours are "experienced". In general, from the author's experience at the 28AD, these measures of

experience are viewed with varied levels of disbelief).

These references are so broad as to be meaningless. The only people that they exclude from the "fully experienced" category are those recently graduated from primary crew training at the 552 TTS. Therefore, the kernel DSS that was designed was developed to address the crew experience issue. Specifically, the kernel system allows managers to graphically profile *current* experience of crew positions with a fair degree of detail, rather than examining them in the current arbitrary, binary fashion. (At some future time, a referent curve of minimum expertise levels in each experience category should be developed to allow the manager to assess how close he is to a tolerable manning profile. Until that time, managers will have to make determinations on the desirability of the experience profile from the gross pattern evidenced in the graphical display).

Choosing a kernel DSS to address current experience in a crew position makes good sense for many reasons. These reasons are introduced here, and discussed in the following section of this chapter. The first reason selecting the above kernel is that it gives managers a capability that they want. Second, even though it does not directly address the need to correct the current short term management approach to the acquisition process, *actions taken as a result of decisions based on experience level estimates will not aggravate AWACS manning level conditions.* Third, it allows managers to use an experience profiling tool and refine it before work is expended in building the more complex profiling tool needed to project experience levels in future years.

Lastly, it is one area of the acquisition planning process where a concerted effort is needed to achieve *any* results. The value of giving users something they desire is self evident. The other three issues are discussed next.

**Rationale for the Kernel Selection.** The capability to examine current experience levels allows managers to approach the acquisition process with an ability to address needs that he cannot currently assess. With this capability, he can take action to correct experience deficiencies by altering the types of people acquired. This augments his management capabilities without altering his current management scheme, *which only addresses identifying the number of people to be acquired.* Since the manager is not changing the manner in which he decides how many accessions are needed, experience profiling cannot aggravate AWACS manning relative to the current management scheme. The current acquisition procedure is simply not affected by it.

The net result of the kernel DSS is an ability for the manager to identify times when AFMPC must make some of the annual crew acquisition come from sources with either 1) AWACS experience (i.e., allow AWACS to recapture previous AWACS resources), or with 2) transferable experience (e.g., pull computer technicians into the CDMT position, rather than bringing in brand new Air Force acquisitions). These conditions can occur when the current aggregate experience of the crew position is low and the addition of totally inexperienced personnel to the position will only aggravate the condition. Therefore, the effect of the kernel DSS will be to elevate the experience level of the crew force for some

extended period of time. (Even if elevating the experience level of the crew force were not necessary, it would certainly not be damaging to have a crew force "overly rich" in experience).

Referencing the point about letting managers use a "simple" experience profiling tool, there are two reasons for implementing the chosen kernel. In the first place, the basic work required for the long term experience profiling is embedded in the kernel system. The basic issue of how to build an experience "score" is addressed here. Second, projecting profiles requires the ability to accurately project manning losses and the development of an apportionment scheme for any factors that impact experience, e.g., if flying hours are a significant factor in determining experience, all projected AWACS flying hour allocations must be distributed over the crew force in some manner to project how the individuals in it gain experience. Resolving these issues will entail a significant effort. Before the effort is expended, the basic experience profiling capability should be used extensively to: 1) familiarize managers with experience profiling, and 2) refine the experience scoring methods if managers feel it is necessary.

Finally, experience is an acquisition issue requiring a concerted effort if the manager's capabilities to address the issue are to be improved. While the crew managers currently deal with acquisitions on a near-term manning level basis, improvements in AWACS manning stability can be achieved with relatively modest effort. As discussed in chapter two, fluctuations in AWACS manning are cyclic in nature. Recognizing this, if the past annual final PFT acquisitions are examined to

determine where peak acquisition demands occur, the cycles can be damped by over-acquiring personnel in the period just before these peaks. In contrast, there is no usable information on experience, since experience has been ignored in past acquisition management. Any attempt to directly deal with experience required a "start from scratch". The kernel DSS provides that start.

With the above understanding as to why the particular kernel DSS was chosen, the remainder of this chapter discusses the modeling methods examined to develop experience scores and a test implementation using a spreadsheet environment to examine the aggregated experience scores.

## Experience Score Modeling Examination

Three different modeling approaches were examined for developing experience scores for the individuals in each crew position. These were: 1) logistic regression with more than two categorical responses (10 in this case), 2) MCDM techniques that elicit and quantify experts opinions to produce "scores", and 3) multiple regression with a binary categorical response. Each is discussed below.

**Logistic Regression.** Logistic regression approaches to developing experience scores suggest themselves because, as stated in chapter 2, empirical evidence suggests that response functions developed using categorical dependent variables will frequently be curvilinear. Logistic transformations of the response function produce responses of appropriate shape and have the desirable property of being asymptotic to the extreme values of the response, i.e., predicted values produced using the logistic response function will not fall outside of the range

of the categories of the original response [Neter, et al : 356-363].

Taking a logistic regression approach to this problem requires that the current crew force be separated into distinct categories of experience. Therefore, this approach would not be purely a regression approach, but would require some preliminary work to categorize the members of each crew position. Multi-Attribute Decision Analysis (MADA) techniques could be used to get "expert evaluations" of the various crew members.

Unfortunately for the current problem, logistic regression requires large samples at each of the possible combinations of input factors to weight the regression appropriately [Neter, et al : 364]. For the current problem, the largest crew force is in the 250 person range. If only four predictors at two levels are used, the largest sample for a given combination of inputs is only 15, which is insufficient. (Given the current perceptions among AWACS experts as to what factors may be useful for determining experience, it is unlikely that a reasonable regression can be achieved without more than four predictors constrained to two levels).

Another problem with this approach is related to the expert support required to do the initial categorization of the crew members in the various crew positions. Discussion of this problem is deferred to the next section, where MCDM methods are discussed.

These difficulties with the logistic regression approach removed its use from consideration.

**MCDM.** Multi-Criteria Decision Making techniques suggest themselves as possible candidates for addressing this problem because of the lack of definitive experience measures for AWACS crew members. Lacking suitable measures, the problem can be approached from the perspective of expert opinion. MCDM techniques, particularly Multi-Attribute Decision Analysis (MADA), are ideally suited for this type of approach. Therefore, MADA approaches to this problem were examined. The details of this examination can be found in Appendix F. The major conclusions of the examination are repeated here.

The MADA methodology examined gave results that made sense. However, while the factor set that was examined was quite small, the techniques still consumed a significant block of an expert's time. Further, when multiple experts differ on utilities and weights, MADA has some problems. Various concordance measures are available for determining whether differences observed between the elicited values are significant. Unfortunately, when the concordance measures indicate significant disagreement, MADA currently has no generally accepted means for resolving the dispute. These differences in expert opinion are bound to arise when these techniques are applied to the DSS considered here. How they are resolved is critical if these techniques are used.

The most significant problem for this particular application was the time consumption mentioned above. The level of expert involvement required to implement this type of strategy is enormous. For the examination of MADA, weights and utilities were only developed for two factors. The process still took over six hours to accomplish, using a

reasonably friendly software package. This time issue is critical for the DSS. The people who will be queried in this process at Tinker AFB are, first-and-foremost, flyers who have an erratic and very full flying schedule. Attempting to corral experts to repeat the MADA approach for each of the 12 crew positions, using multiple factors and repeating the process multiple times as the system evolves, would probably kill the DSS development outright.

The reason the process consumed so much time was that the experts being consulted, in general, have no background in probability. Both the utility and weighting elicitation process are heavily dependent on the expert's ability to assign probabilities to the choices presented during the elicitation process. The major problem encountered was that, even using a 50-50 gamble (which Holloway indicated is generally the most easily understood), the decision maker being queried could not build a utility curve that matched his estimations, *even when he had a clear perception of what the curve should look like.* People in general do not deal with probabilities well, and this experience indicates they have particular problems estimating the relative probabilities for two different bounded ranges (not including either extreme) in the interior of the space they are considering.

For these reasons, MADA was removed from consideration for this application in the DSS. However, MCDM in general, is a tool that will necessarily be applied to other areas of the final DSS. This is discussed in chapter 5.

**Multiple Regression with Binary Responses.** During the examination of MCDM techniques the idea of using a multiple regression approach with a binary response surfaced as an appropriate technique for experience modeling . One fact that was uncovered while surveying experts for the MADA evaluation was that a fairly rigorous categorization based on expert assessment of crew member expertise already occurred in AWACS. This being so, there existed a binary response that categorized crew members as: (1's) -- definite experts or as (0's) -- the rest of the crew force. (All experts do not necessarily fall in the expert category). With a binary response, a multiple regression is feasible [Neter, et al; 354-361].

While a multiple regression is feasible for the binary categorical response, there are two problems. First, two of the assumptions of least squares regression do not hold. Least squares regression assumes that the error in the regression is normally distributed with a mean of zero and with constant variance. Since the response is binary, the error in the regression can only take on two values. This being the case, the error is not normal. Similarly, the variance of the error is dependent on the response level, and is therefore not constant. Second, there are constraints on the possible values of the response. The interpretation of the output of the regression model is somewhat different than in other regression formulations. Since the response is binary, the expected value produced by the regression model is *just the probability that a particular combination of regressors will result in an "expert" classification.* Since the output of the response function

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is a probability, it is constrained to the region from 0 to 1.

These problems can be successfully dealt with. The lack of constant variance can be corrected for by using a weighted least squares fit. The constraint issue can be dealt with by ensuring that the response cannot fall below zero or above one over the range of the predictors or by transforming the predictors. Finally, while the error terms are not normal, for sufficiently large samples inferences about the regression results can be made as if the error were normally distributed. (In general, sample sizes greater than 30, are sufficient for treating the results as having come from normal populations [Devore : 260]. Samples for all crew positions are larger than this).

The approach just discussed is feasible and easily implemented. It is transparent to the user in that it does not consume valuable expert time, but its assumptions can easily be documented for expert review. It was therefore chosen as the modeling technique to be employed in the kernel DSS. Implementation is discussed in the remainder of this chapter.

## Kernel Implementation

The kernel was implemented for test purposes using Borland International's Quattro Pro spreadsheet environment. This environment was chosen for multiple reasons. First, Quattro Pro acts directly on multiple file formats, one of which is DBASE III. An abbreviated form of the standardized personnel management database, which is based on DBASE III (and which was discussed in chapter 3) was available to develop a preliminary kernel DSS.

Second, as compared to ENABLE, which was used in the previous DSS in this area, Quattro Pro has much better response times. Borland's memory management system used in Quattro Pro is much more sophisticated than ENABLE's, significantly improving Quattro Pro's speed. Possibly more important Quattro Pro does not support all of the capabilities that ENABLE does, reducing its overhead, and its graphics capabilities are much better integrated to the spreadsheet than ENABLE's were.

Finally, Quattro Pro is almost totally configurable to specific applications. Full menuing capabilities (that replace the normal spreadsheet environment menus) are provided, multiple windows are available for changing displays rapidly, and mice are fully supported (this feature was not used). As such, the user environment in Quattro Pro could be tailored to match the environment envisioned in the storyboard almost totally (the main exception was to place the system support options as a menu item on the top menu bar).

**Pulling the Pieces Together.** In the kernel DSS, multiple regression with binary responses was conducted in a PC based statistics package, Statistix II, using the abbreviated database mentioned above. (Results of this regression are discussed in Appendix E). This modeling technique is implemented with relaxed tests for confidence intervals, as suggested by Deming [Deming]. (This issue is discussed in Appendix E).

After examining the regression results and determining an appropriate model, the appropriate database fields were read into Quattro Pro, where the model was applied to each record of the database to build an experience score.

Scores in the database were separated into three distinct groups: people who were known to be departing AWACS, people who were currently not in AWACS (whose records were in the inactive portion of the database) but who had been gone long enough to be due to PCS, and the rest of the people in the crew position. The scores for each group were then aggregated using Quattro Pro's capability to examine frequency distributions, and the results written to a histogram to display the score distribution. (This graph is part of the spreadsheet. A transition to another program module is not necessary before it can be viewed, in contrast to ENABLE). The resulting graph was similar to that shown in Figure 7.

The results of this effort were a system that operated and which provided an understandable display for the current experience of the crew position profiled. Building the system in Quattro Pro involved two deviations from the design specified by the storyboards. First, the user interface defined in the storyboards was modified. It was built as specified with the exception of placing the system support commands in a sub-menu off of the decision command menu and placing the memory aid line below the main menu, rather than above it.

It was not absolutely necessary that the system support commands be moved to the top menu; a menu at the bottom of the screen could have been implemented. However, flexibility in selecting from this menu would have been limited, and would have "felt" different from the selection process used in the rest of the system (i.e., mouse and cursor selection of the system support options on a bottom of the screen menu

would not have been possible).

In contrast, the memory aid line had to be moved. This is because Quattro Pro reserves the line above the main menu line for its own use.

The other deviation from the storyboards involved placement of the two graphs being displayed. For resolution reasons, the graphs were placed one below the other instead of side-by-side. While Quattro Pro is exceptionally flexible, it does place some restrictions on the user. One of them is the lack of control offered to the user over some of the "cosmetics" the system's graphics. Large boarders are placed around graphs; this required that the two graphs be stacked if they were to be viewed at the same time. Further comments on Quattro Pro's usefulness as a DSS environment can be found in the following chapter, which details the conclusions and recommendations that resulted from this DSS research effort.

## V. Conclusions and Recommendations

### Background

When a request for an AFIT thesis proposal was received by the 28 AD in early 1987, the author proposed that the issue of supporting AWACS personnel managers be examined. The proposal was prompted by the lack of understanding of long term personnel issues exhibited by PFT attendees during the course of numerous PFT conferences. When the proposal was acted upon by Schneider, the author was the point of contact at the 28 AD for the research effort, acting as the user's "representative".

Many of the objectives outlined in the original proposal were never addressed (prior to embarking on a thesis, the author had no appreciation of the constraints that limit a thesis' scope). Further, the majority of the issues that were addressed were approached from a perspective alien to that envisioned when the proposal was made (i.e., Schneider's research addressed the problem largely from the perspectives of TAC, not the 28 AD).

The ways in which the previous research was limited, the directions it took, and the apparent inability of the "user" to influence the course of the research were never understood by the author and prompted him to re-address the problem in this thesis. The process of viewing the same problem from two perspectives has been an eye opening experience, and has certainly impacted the types of conclusions and recommendations that resulted from this research.

This chapter contains the conclusions and recommendations that

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resulted from this research effort. The observations documented here are separated into two major groups: 1) those that deal with development of DSSs in general, and 2) those that address the future of the specific DSS examined in this research.

## General DSS Development

### 1) DSS development and separation from the user's environment.

Conclusions. DSSs cannot be successfully developed at a location removed from the user. This conclusion results from three areas of difficulty which are discussed next.

First, communications and accountability problems arise. While storyboarding is an outstanding communications tool (discussed later in this chapter), it cannot correct the communications problems related to timely feedback. Without constant communication, a necessary sense of accountability between the developers of a system (designer, user and builder) is lost, resulting in a design process that wanders. (This issue is also discussed later in this chapter).

Second, if the DSS is developed away from the user's environment, the system will assume the designer's character, regardless of the designer's good intentions. Without constant communication and immediate feedback, the designer has to act on his perceptions, with the result that the designer's views are built into the system. (At the very least, the adaptive development cycle is prolonged while the user weeds out those elements that don't support *his* needs).

Third, constant interaction with the user is the only way to determine what he knows. A general complaint of system builders is that

users do not know what they want.  After the experiences involved in this research, another observation should be "users do not know what information they have that is applicable to the solution of their problem".

All three of these difficulties are at the root of why the author didn't understand the course Schneider's research took, which resulted in his pursuit of the same research area.

**Further Observations.**  Valusek makes a distinction between rapid prototyping and adaptive design [Valusek].  Both design methods are geared to developing portions of a system and "growing" the final system by merging the previously delivered portions.  The distinction that Valusek makes is that rapid prototyping occurs at the developer's facilities and is "delivered" to the user in pieces, whereas adaptive design occurs at the user's facilities.  This difference is critical, and makes one wonder if rapid prototyping isn't traditional systems development in disguise.  If the designers and builders are not at the user's facility, they cannot "wallow" in the problem or determine what data the user actually has that may be applicable to the problem.  They have to totally rely on the user's description (read specification) of his needs.  Separating a DSS's development from the user's environment results in a rapid prototyping approach, and entails building the DSS to a "spec" in that the system is built to some *static standard* between deliveries, just as is done in traditional systems development.  (Not only is the system being built to "specs", it is being built to a spec multiple times).

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Adaptive design is geared to getting away from specs, or at the very least, letting the spec "float". The constant interaction between the system developers results in a more "even evolution" of the system, rather than a process that involves taking two steps forward and falling one step back when it is discovered "too much progress was made" (in the wrong direction).

Both Schneider's and this research effort to support the AWACS personnel acquisition process are guilty of falling back to a rapid prototyping approach, particularly when they are viewed together. This research was pursued because Schneider's DSS evolved in a direction that did not suit the users, which required it to be corrected. The DSS developed as a result of this research may be equally guilty. The only correction for this situation is for any further development of the DSS to occur at the 28AD, *where communication with the user and system assessment by the user can occur during development.*

**Conclusion.** Research into DSS development, particularly with regard to adaptive design, needs to be done at a real user's site, and removed from the purely academic environment. This is a direct corollary of the above discussion.

**Recommendations.** This DSS should not be examined for further development in thesis efforts. All future evolution of the system should be done by 28 AD analysts (28 AD/XOS). While the analysts at the 28 AD may not have familiarity with the Operations Research tools that bear on the problem, learning specific tools is easily corrected. The difficulties in acquiring data and understanding of user's needs from a

distance is not.

## 2) Storyboarding as a communications tool.

**Conclusion.** Storyboarding is a tremendous tool for clarifying user desires and designer intentions. The author's first exposure to storyboards was during Schneider's research in the AWACS acquisitions area. At all times, the intent of the designer (Schneider) was clear to the user (Holt), and desires for the system could be clearly stated by referencing desirable and undesirable features of the storyboards. (As discussed above, however, the power of storyboards to communicate intentions and desires was insufficient to overcome other communications obstacles).

**Conclusion.** Storyboards fill a very fundamental role in the adaptive design process. Determining user requirements is a difficult process that entails two distinct phases (IRD and IRA). Both the IRD and IRA processes can be well structured by storyboarding. The storyboards lend a "tactile" element to the study information requirements. Users and designers can "grasp" their needs because they are clearly and simply stated, rather than floundering to an understanding of needs while wading through a morass of verbiage that obscures the communications of needs. *Pictures are worth a thousand words.*

**Recommendation.** An effective, general purpose storyboarding tool should be developed. The ability to build a running "dummy" system in storyboard form that responds to user inputs would be a valuable system development tool. Further, it could significantly speed up the

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storyboarding process, by placing the storyboards in an environment

geared to building and editing them. (Word processors *are not* effective

environments *for* building storyboards).

### 3)  DSS design as an individual effort.

**Conclusion.**  The importance of synergy can never be overrated.

Dealing with complex issues as individuals is not as productive as

dealing with it as a team, *if the team is built from the right elements.*

In the adaptive design context, the design team can be considered to

consist of the designer, builder and user.  Together they capture user

requirements, determine user capabilities, identify useful data, choose

applicable modeling techniques, identify technical constraints that may

impact a system's development, ... and address the many other functions

that must be considered in a design process.

Each of these people brings his own domain expertise to the design

process.  However, the user comes up short in the domain area when the

design process leaves the "this is what I want" stage and enters the

"how do we give him what he wants" stage.  The user's domain expertise

is crucial to a system's development. It is, after all, his problem that

is being addressed.  But for systems design to transition successfully

to implementation, many questions need to be answered in areas where the

user has no expertise, and more, does not even understand the language.

For these questions to be resolved effectively, designers and builders

need to communicate with others who speak the language of systems

development so they can sharpen their insights and ferret out their

errors and false assumptions.  The lack of a "sounding board" to help

sharpen insights was a significant handicap in approaching this research as a lone designer.

**Recommendation.** DSS development should proceed from a team perspective, *where the team consists of multiple designers, builders, and users*, not one of each.

**Conclusion.** A clear distinction in the functions of each member of a design team is a necessity, and builders should never be confused with designers.

This research was conducted by a "builder", i.e., someone used to dealing with the solution of problems, not their formulation. Builders assume that if somebody has a problem to be solved, they know what the problem is and how they want it solved. Their job is to implement the desired solution. Therefore, builders view the system as the product, totally overlooking or ignoring the fact that, for a DSS, the *decision is the product*. Building becomes the important task, resulting in design functions being subsumed by building functions.

Builders also tend to look at problems from a depth first rather than breadth first perspective. They focus on small portions of a problem and deal with it, approaching problem solution "modularly". A consequence of this approach is that, until it is dealt with successfully, the smaller problem becomes "the problem". This cripples a builder's ability to act as designers, since the designer must be concerned with the entire problem area.

To overcome these problems, there must be a clear distinction as to who the designer is, and that person cannot be the builder. Design

functions are too important to be entrusted to somebody with a builder's perspective.

**Recommendation.** Separate responsibilities -- and never let a builder be responsible for design functions (otherwise "design" will occur in an erratic manner).

### 4) DSS development and technical constraints.

**Conclusion.** Because of the speed with which basic blocks of a DSS can be examined, spreadsheets allow rapid assessments of the concepts embodied in the storyboards.

The value of the spreadsheet environment lies in the speed with which a system can be prototyped. For the DSS developed in this research, a spreadsheet (specifically Quattro Pro) was flexible enough to implement the entire system's control structure (embedded in the menuing system and the memory aid system) as specified in the storyboards, with only minor deviations. The environment also allowed the disparate data necessary for the kernel's functions to be viewed and manipulated, with the necessary models being built into the spreadsheet.

**Conclusion.** Spreadsheet environments are currently inadequate for final implementation of DSSs. Current user programming capabilities (macros) in spreadsheets are not powerful enough to build systems that need minimal support. This is particularly apparent when external databases are being queried by the spreadsheet.

For this DSS, building a general database interface with a great deal of conditional flexibility was needed if a system were to be built that required minimal modification of the core spreadsheet environment.

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Model specifications (that were subject to change) needed to be passed to the spreadsheet. The same was true for data specifications (which were dependent on the model specified). Since both of these elements were subject to change in dimensionality, the specification of calculation areas in the spreadsheet for specific modeling operations became a messy issue that could only be solved by execution of conditional programs that exceeded the capacities of the macroing language of the spreadsheet.

**Recommendation.** Until such time as effective DSS generators are available, spreadsheet environments should always be considered for quick assessments of DSS design elements.

**Further Observations.** Development environments not specifically designed to support design in a particular application area are dangerous to the overall design process. They impose technical constraints on a system's development that may not be appropriate. Worse, they breed commitment to the system in its current stage of development, when this commitment is not justified. It is very hard for a system's developer to abandon past development because of the constraints of the environment he is operating in; it is easier to change the "requirements" of the system to be developed. This is particularly apparent in the DSS Schneider designed for AWACS. Schneider's environment, ENABLE, imposed significant constraints on the DSS design (this is conjecture on the authors part, but is consistent with his experience, and goes a long way to explaining the course Schneider's DSS took).

**Conclusion.** DSS development in the adaptive design paradigm without effective DSS generators is severely crippled. Turn around time for useable system enhancements are simply not short enough for the adaptive design process.

Until such time as a development environment is available that is flexible and extensive, development will have to occur in one of two environments. First, design can occur in spreadsheets, as discussed above, where assessments of DSS design elements can rapidly be made. When the design element has been "shaken down", it can then be implemented in stand alone code for integration into a final system. Unfortunately, this is very wasteful of the effort that goes into developing the spreadsheet capability.

The other possibility is to build the system in stand alone code from the start. This is a possibility, but only if *large* programming toolboxes applicable to the task are available. Without the necessary toolbox (which constitutes the beginnings of a DSS generator), development time for the basic system components will make delivery of DSS components impossible in adaptive design time frames.

**Recommendation.** A major research effort should be started in the area of developing specifications for DSS generators.

5) The critical nature of assumptions.

**Conclusion.** The critical nature of assumptions cannot be overstated for DSSs. When a user knows what decision needs to be made and resorts to a DSS to arrive at his decision, he has lost control of the decision process and rendered the decisions arrived at suspect if he

does not know what assumptions have been implemented in the DSS's design. **All modeling techniques** entail assumptions; some are related to how data is treated, and some are related to the applicability of the various modeling techniques used. All of the assumptions made using the **DSS modeling technique** need to be "examinable" if the decision maker is to make valid decisions.

**Recommendation.** Some structure similar to the "ASSUMPTIONS" button presented by El Sherif, et al, needs to be incorporated in all DSSs, and all assumptions need to be fully documented.

## The Specific DSS

### 6) This DSS and where to go in the future.

**Conclusion.** Expert opinion is going to play a major part in whatever quantification scheme is proposed for the AWACS capabilities assessments. This is also true for determining an appropriate baseline for desired experience distributions in the different crew positions. This is because there are currently no hard and fast measures for these areas. MCDM techniques are very relevant to this area.

**Conclusion.** Synergy, as discussed for design team issues, also exists among modeling techniques. The examination of MADA for quantifying experience led to identification of criteria by which a subset of a crew position could be categorized in experience. The regression technique specified for use in the kernel (which overcomes the time issues that make application of MCDM techniques to the problem untenable) was only able to be used because of information uncovered using MADA techniques.

**Recommendation.** Multiple modeling techniques should be examined for applicability to each phase of this DSS's development.

**Conclusion.** The regression method employed in the kernel has some potential stumbling blocks.

As discussed in the previous chapter, regression results only make sense if the response is bounded by zero and one. When a set of factors is determined to be significant in predicting membership in the "expert class" (defined by StanEval personnel and instructors), the range of the factors needs to be examined to ensure that they don't force the response into an un-allowed range. If infeasible responses are encountered, transformations of the predictors may be necessary. *Another possible strategy is to examine the predictors, to see if it makes sense to "cap" the values they can take on.* For example, if flying hours are a factor in the regression model, it may be that it makes no sense to count flying hours above 2000 hours. Marginal flying hours above this number may not impact experience significantly. This type of "call" is an expert judgement call -- MCDM techniques may be useful in evaluating these types of questions.

**Recommendation.** Always keep in mind that regression (like all other modeling techniques) *only provides guidance.* The analyst must bring his/her judgement to bear on what the results mean, and must also keep data implications in mind, if effective models are to be built.

**Conclusion.** This DSS is going to require extensive support from the 28 AD analysis office. Implementing the entire system discussed here will be a major undertaking. This effort is one that the 28 AD

analysis shop, as it is currently configured, is well equipped to address, given the combination of analysts, programmers and a supervisor with extensive systems development background. However, the commitment required from this office is going to extend well beyond "system delivery", where system delivery refers to a time when it appears that the system has evolved to a fairly stable state. At this point, when it appears that user needs are being met, *support requirements for this system are still going to be extensive.*

As changes in the crew force come about due to changed acquisition practices, it must be realized that models developed to address earlier crew compositions will have to change — **and regression cannot be automated.** As discussed above, the analyst is an integral part of the regression modeling approach, and will therefore have to be an integral part of the DSS's operation. The analyst must be involved to interpret the regression results and to determine the most effective model to describe what is observed.

## Summary

As a learning experince, the value of this research cannot be overstated; its impact on the author has been immense. The different natures of design and building were "discovered" (and constantly re-discovered) during the research, resulting in the realization that good design does not often occur by happenstance, it is hard work.

For the Operations Researh world, the insights pertaining to division of labor in DSS development and the necessity for good DSS development tools are important, and are areas requiring further study.

# Appendix A

## Concept Map

The concept map describing the AWACS personnel acquisition process is included on the following two pages. This concept map is presented in a hand drawn form for two reasons. First, a concept map is *only a guide* to understanding the intricacies of the problem being addressed -- *it should never be viewed as a product that defines the problem.*

A "perfect" concept map could be construed to be a product which fully describes a problem and implies that the problem is completely understood. This is nonsense, and could stifle further exploration of the problem. Making the concept map "perfect" is, therefore, counter productive. (Also, effort expended making the concept map "pretty" can better be spent addressing how to solve the problem which the concept map describes.

Above all, the concept map must be viewed for what it is -- a useful tool, **not a product in its own right.**
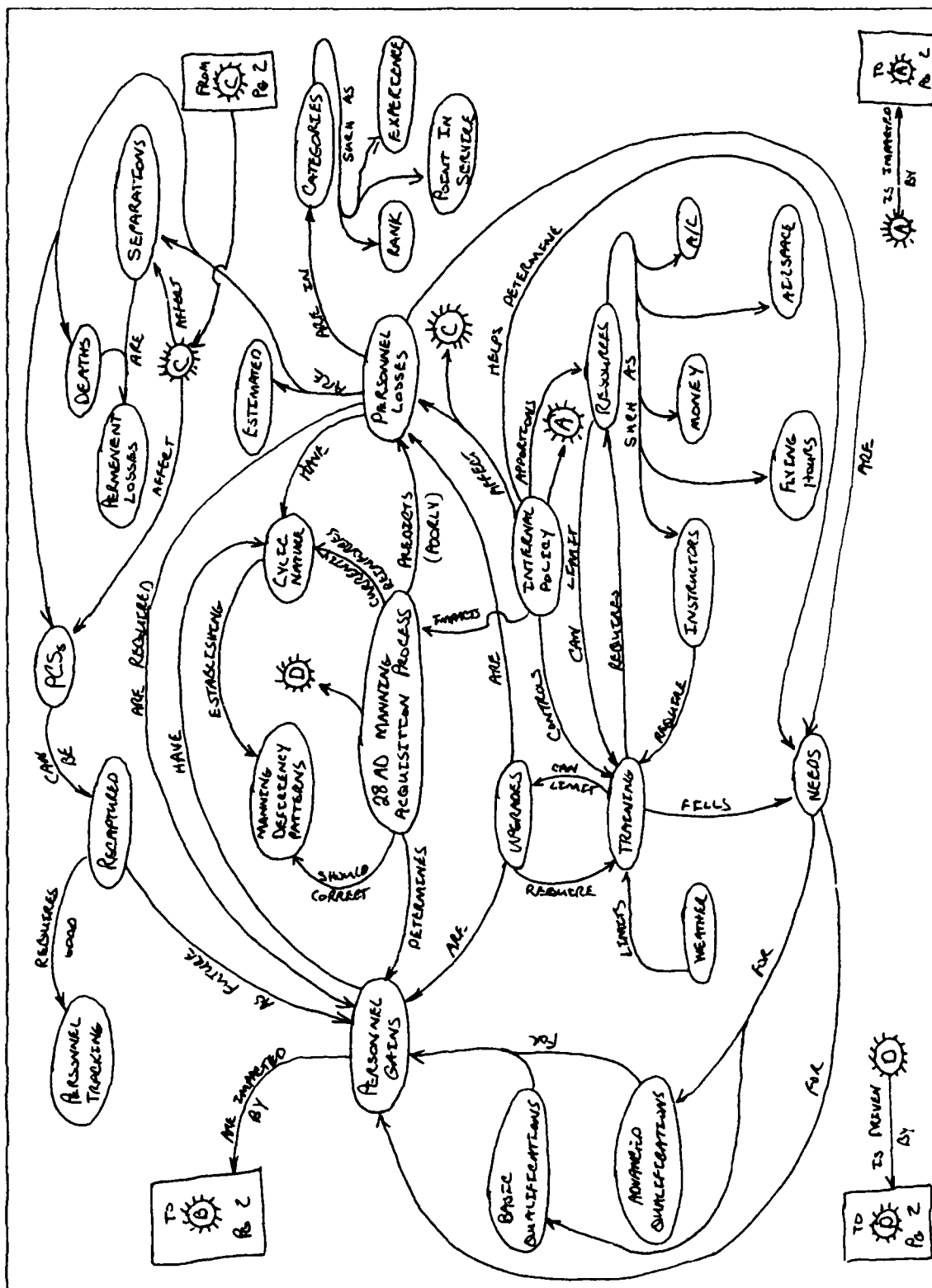
Figure 11 (part a) — Concept Map for AWACS Personnel Acquisitions

Figure 11 (part b) - Concept Map for AWACS Personnel Acquisitions

# Appendix B

## Storyboards

The storyboards describing the AWACS PERSONNEL MANAGEMENT ACQUISITION SYSTEM follow. They are divided into five functional areas that indicate the issues they address in the system's operation. These areas are:

1) System functions — addressing how the system is structured and how it is used;

2) Assessments of current crew position profiles — the user needs to understand where he currently stands before he attempts to plan acquisitions;

3) Acquisition planning and assessment of long term impact — the user schedules acquisitions under different assumptions and examines the impact the planned acquisition has on the crew position;

4) Assessment of personnel issues on mission capabilities — the manager needs to know how to balance conflicting acquisition needs. System's performance provides the measure, and;

5) Provisions for the managers to examine low level information that impacts their decision — e.g., examining the personnel databases and accessing information on scheduled changes to AWACS manning that will impact his needs assessments.

Each storyboard has a description of its major features. These descriptions are not stated explicitly in terms of ROMC. Rather, the

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descriptions are in terms of what the user needs to know to determine
that the system meets his needs. (The correlation of the description
elements to the elements of ROMC should be self-evident to readers
familiar with the ROMC structure).

# System Control and Help

```
+==================================================================+
|       AWACS PERSONNEL ACQUISITION MANAGEMENT SYSTEM              |  <-- (1)
+----------+----------+----------------+------------------+----------------+
| POSITION | SCHEDULE | MANNING PROFILE | AWACS CAPABILITIES | FORCE STRUCTURE |  <-- (2)
+----------+----------+----------------+------------------+----------------+
|                                                                  |
|                                                                  |
|              Welcome to the 28 Air Division AWACS Personnel      |
|                   Acquisition Management System                  |
|                                                                  |
|                                                                  |
|              System files are now being accessed                 |
|                                                                  |
|                                                                  |
|                         Please wait                              |  <-- (3)
|                                                                  |
|                  (Approximate time : 1 minute)                   |
|                                                                  |
|                                                                  |
|                                                                  |
|                                                                  |
|                                                                  |
|                                                                  |
|                                                                  |
+------+--------+--------+-----------+------------+----------+------+-----+
| Help | Notepad| Hookbook| Assumptions| Prior Screen| Main Menu| Print| Quit |  <-- (4)
|  F1  |   F2   |   F3    |    F4      |     F5      |    F6    |  F7  | F10  |
+------+--------+--------+-----------+------------+----------+------+-----+
```

Figure 12 - System Structure Representation

This is the entry screen for the support system. The system is specified on the *memory aid bar* (1) and the major system options are designated on the *system command menu bar* (2). The *system work and display area* (3) contains a message welcoming the user informing him that there will be a brief wait while data files are accessed. The major system support functions are contained on the bottom menu, the *system support menu bar* (4).

**System Command Bar**: The major decision areas are separated from the rest of the system and placed on the top command bar. They are also in all caps as a further reminder that they are decision area commands. Descriptions of the commands can be accessed through the help command (F1). Added information for selected options follows.

POSITION: The POSITION option allows the user to filter the database so only the crew position of interest is evaluated during the current session. A specific position must be designated for the scheduling routine and some of the manning profile routines. If a position hasn't been named prior to selecting the SCHEDULE option or the affected subsets of MANNING PROFILE option, the system will self-select the POSITION option before continuing.

SCHEDULE: This is where the bulk of the work with this system will be conducted. Current position in manning and future projections are used in a "What-if" cycle to arrive at manning acquisition decisions. A significant feature of this capability is the ability to show TAC/MPC the immediate and long term consequences of their acquisition policies, in a quantitative format.

MANNING PROFILES: This options has a two-fold function: to provide background at a low level (a subset of the actual database driving the models), and to allow the user to make high resolution assessments of the experience (current and near term change) of the crew position he is responsible for.

**System Support Bar:**   The system support bar provides the support

required of the system that is not directly related to the decision

elements of the process being supported.   These commands are separated

from decision commands by position and by the typographic form of the

commands.

   Help:   Provides context sensitive insights and direction that clarify
the decision process and the software's operation.

   Notepad:   Provides user with a pad to document his insights,
questions, and ideas about personnel acquisition.

   Hookbook:   A notebook for system related ideas or comments.
(Any sequence of menu selections in a particular session are stored in a
buffer and recorded as memory aid entries on the notepad and hookbook
whenever they are opened).

   Assumptions:   At any point, the user can query the system to see
what assumptions have been made in the way data is treated.   This is
particularly useful for ensuring the user understands what models are
doing, and what the weaknesses of their operations may be.

   Prior Screen:   Allows user to backup 1 screen per keystroke.   A
screen is defined as any display that is uniquely different from the
previous one, i.e., if a display has a sequence of commands performed on
it that adds new material, each stroke of F5 will back the user out from
the results of the last command.

   Main menu:   Takes user to the system command bar for his next action.

   Print:   Make hard copy of current screen and the materials being
referenced, e.g., entire roster being referenced, of which only a
portion is visible on the screen.

   Quit:   Returns user to operating system or shell, with an option to
save any work.


**Major System Control Features:**   The major control features of the system

are embodied in the menuing structure displayed on the screen.   Further

structure is provided by limiting access to certain system command

options when others are active.   In these instances, commands that

cannot be selected from within current operations disappear from the command menu. For example, when MANNING PROFILE is selected, the only other system command option that remains on the menu is the POSITION option, allowing profiles to be specified by crew position (see the following story board).

**Memory Aids:** Memory aids are also largely embodied in the systems presentation format. Main system commands that are currently active remain highlighted; sub-level options and the choices made at the sub-level will be displayed on the Memory Aids Bar (2). (See the third story board for clarification). As a further aid to memory, levels of sub-menus are kept to a minimum; the user's understanding of where he is in the decision cycle in enhanced by keeping command trees short.

```
┌─────────────────────────────────────────────────────────────────────┐
│  ┌───────────────────────────────────────────────────────────────┐  │
│  │           AWACS PERSONNEL ACQUISITION MANAGEMENT SYSTEM        │  │
│  ├─────────┬──────────┬───────────────┬─────────────────┬────────┤  │
│  │ POSITION│ SCHEDULE │ MANNING PROFILE│ AWACS CAPABILITIES│FORCE STRUCTURE│ │
│  ├─────────┴──────────┴───────────────┴─────────────────┴────────┤  │
│  │                                                               │  │
│  │                                                               │  │
│  │    Main menu options may be chosen from the system menu bar by selecting │
│  │    the highlighted character, by pointing and clicking with a mouse or by │
│  │    placing the cursor in the desired box and striking return. │  │
│  │                                                               │  │
│  │                                                               │  │
│  │    POSITION            - Select the crew position of interest.  Default │
│  │                          is all positions being evaluated.    │  │
│  │                                                               │  │
│  │                                                               │  │
│  │    SCHEDULE            - Plan personnel acquisitions strategies. │  │
│  │                                                               │  │
│  │                                                               │  │
│  │    MANNING PROFILES    - View current manning, experience profiles, gain │
│  │                          and loss estimates and their impacts. │  │
│  │                                                               │  │
│  │                                                               │  │
│  │    AWACS CAPABILITIES - Assessments of AWACS systems effectiveness as │
│  │                          impacted by personnel issues.        │  │
│  │                                                               │  │
│  │                                                               │  │
│  │    FORCE STRUCTURE     - View weapons system factors driving personnel │
│  │                          requirements.                        │  │
│  │                                                               │  │
│  │                                                               │  │
│  │                                                               │  │
│  │    System support bar options may be selected by designated F keys, and by │
│  │    the methods for the main menu (except there are no highlighted letters) │
│  │                                                               │  │
│  ├──────┬────────┬─────────┬───────────┬───────────┬──────────┬──────┬─────┤ │
│  │ Help │Notepad │Hookbook │Assumptions│Prior Screen│Main Menu │Print │Quit │ │
│  │ F1   │ F2     │ F3      │ F4        │ F5        │ F6       │ F7   │ F10 │ │
│  └──────┴────────┴─────────┴───────────┴───────────┴──────────┴──────┴─────┘ │
└─────────────────────────────────────────────────────────────────────┘
```

Figure 13 - Example Help Screen  --  Decision Command Descriptions

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This is the main help screen that gives a basic description of the main commands on the decision command bar. This is the help screen that is activated if no sub-menu options have been user selected. More detailed information is available by selecting (via mouse or cursors) the command of interest. In general, the help system can be accessed at any time and is context sensitive, with help being provided for the currently active command.

```
 POS: CDMT
┌──────────┬──────────┬────────────────┬──────────┬──────────┐
│ POSITION │          │ MANNING PROFILE│          │          │
└──────────┴──────────┴────────────────┴──────────┴──────────┘
        The MANNING PROFILE option allows you to examine different aspects of
        how experience is distributed in a crew position, and by whom.  Different
        filters are provided to help you assess experience distribution issues.


        Rank filter    :  Specify a rank or range of ranks you wish
                          to examine.  Default is no filter set; all
                          ranks are examined.


        Losses         :  Examine roster of crew members who are projected
                          as losses in the database.


        Gains          :  Examine roster of crew members that are currently
                          projected as inbound.


        Display        :  Roster of all AWACS crew members.


        Experience     :  Graphic display of experience profiles for
                          crew positions.



           Current     :  Shows the experience profile for the crew position
                          as it is currently manned.

           Projections:  Shows projected experience resulting from the manager's
                          proposed acquisitions.


┌──────┬─────────┬─────────┬────────────┬─────────────┬───────────┬───────┬──────┐
│ Help │ Notepad │Hookbook │ Assumptions│ Prior Screen│ Main Menu │ Print │ Quit │
│ F1   │ F2      │ F3      │ F4         │ F5          │ F6        │ F7    │ F10  │
└──────┴─────────┴─────────┴────────────┴─────────────┴───────────┴───────┴──────┘
```

Figure 14 - Example Help Screen  --  Manning Profile Options

This is the help screen that is displayed if help is activated while MANNING PROFILE is selected on the decision command bar. (he memory aid bar indicates that the MANNING PROFILE option is indeed active). Each of the sub-menu options under MANNING PROFILE is briefly described. More detailed descriptions are available by selecting the sub-menu option of interest (by highlighting the appropriate title).

Assessment of Current Crew Position Status

(Entry Level Assessments)

**CURRENT EXPERIENCE STATUS (POS: ALL    FUNCTION: MANNING PROFILE - EXPERIENCE)**

| POSITION | | MANNING PROFILE | | |

EXPERIENCE LEVEL HISTOGRAMS

Authorized:     1282                              Authorized:     1282
Total shown:    1200                              Total graphed:  1200

EXPERIENCE FACTOR
CURRENT WITH KNOWN LOSSES
THE COMING YEAR

EXPERIENCE FACTOR - PROJECTED
RECAPTURING ALL TRACKED PRIOR AWACS
MEMBERS ABSENT AT LEAST 3 YEARS
(THIS IS A BEST CASE PROJECTION)

LOSSES                    BALANCE                    GAINS

| Help F1 | Notepad F2 | Hookbook F3 | Assumptions F4 | Prior Screen F5 | Main Menu F6 | Print F7 | Quit F10 |

Figure 15 - Aggregate Experience Profile for AWACS

This is the main entry screen, and is entered by system default after all necessary data files have been loaded. The first time into the system, the current aggregated experience profile for all AWACS crew positions is presented. After a particular user selects the crew position he will use, the system will subsequently come up with his position profiled. (For high level managers, the profile for all positions is available by setting the position filter to "ALL").

This entry point to the decision process was selected allow managers to understand the current experience profile of the positions they manage before becoming involved in acquiring bodies. Managers will therefore know when acquisition planning starts whether special attention must be given to the types of acquisitions offered by MPC.

The manager gets two profiles. The left profile shows the current status of the crew position and the impact known losses will have on it. The right profile indicates the best profile available if all known "eligible" former AWACers from this position are recaptured from the Air Force manning pool. (If the corrections are not enough, the manager may have to examine the possibility of capturing people with applicable experience).

Position is the only system command menu directly available to the user from the home display. Position filters can be changed directly by hitting "P" or selecting "POSITION" with a mouse or cursors.

Leaving this display requires F6 to be selected to enable access to the whole system command menu bar.
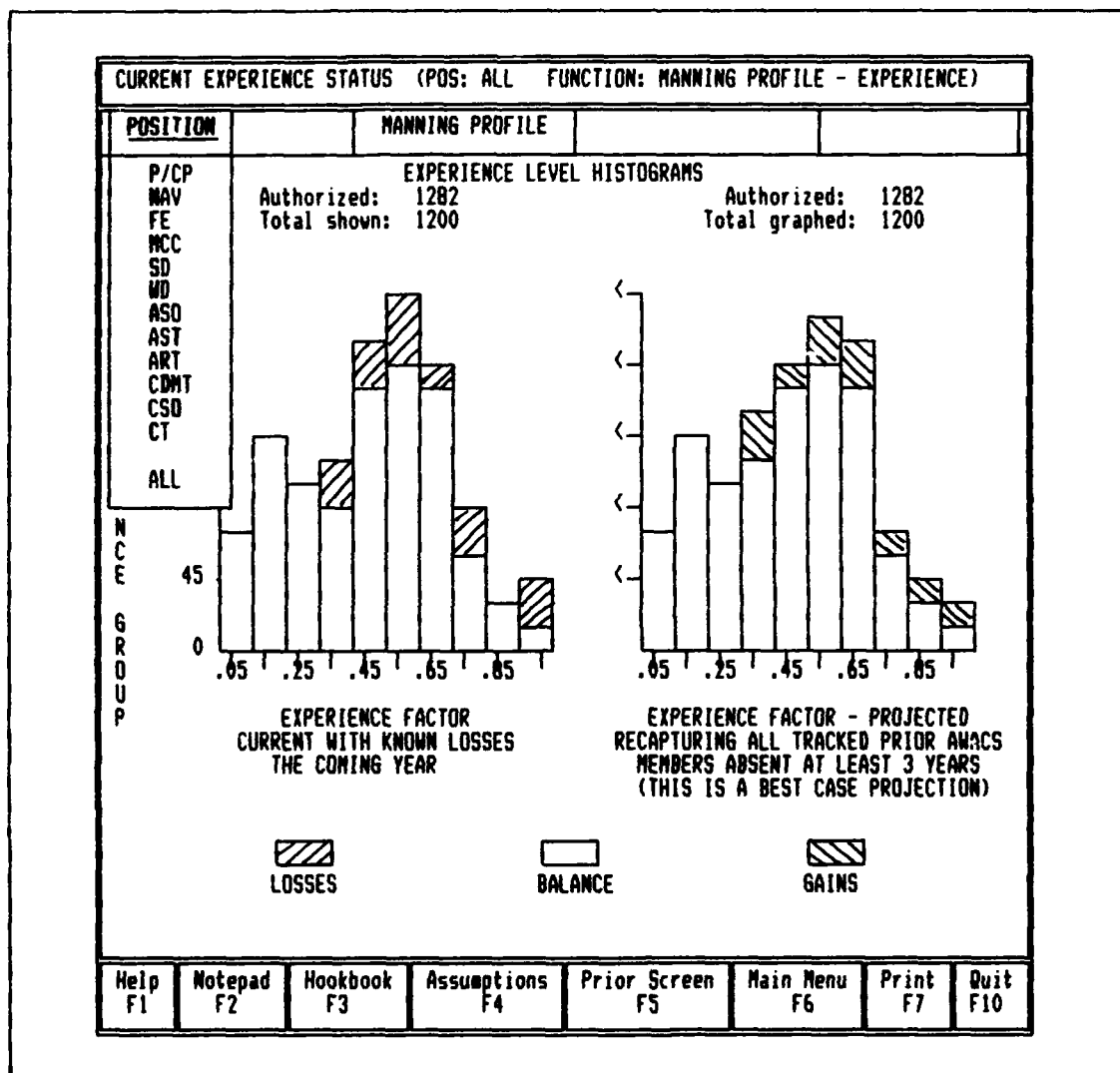
Figure 16 - Setting a Position Filter for Experience

Selection of POSITION drops a pop down menu containing the AWACS abbreviations for all crew positions on the aircraft. Selection is by command letter (highlighted) or by point and click. The default selection is "All".

Selecting Help at this point would spell out the positions associated with each abbreviation, describe the filtering that occurs if a position is selected, and describe why filtering might be desired.

After a position filter is selected, the choice made will appear on the memory aide bare on all subsequent screens as long as the filter is active.

CURRENT EXPERIENCE STATUS (POS: MCC    FUNCTION: MANNING PROFILE - EXPERIENCE)

| POSITION | | **MANNING PROFILE** | | | |

EXPERIENCE LEVEL HISTOGRAMS

Authorized:     86                          Authorized:     86
Total graphed:  80                          Total graphed:  76

# IN EXPERIENCE GROUP

EXPERIENCE FACTOR
CURRENT WITH KNOWN LOSSES
THE COMING YEAR

EXPERIENCE FACTOR - PROJECTED
RECAPTURING ALL TRACKED PRIOR AWACS
MEMBERS ABSENT AT LEAST 3 YEARS
(THIS IS A BEST CASE PROJECTION)

LOSSES          BALANCE          GAINS

Figure 17 - Current MCC Experience Profile

The user operation executed in the previous storyboard selected MCCs for profiling — this is indicated on the memory aid bar. The displayed profiles now reflect MCC experience.

This screen also provide baseline information that is useful to the manager when evaluating a crew position. Information on current authorizations and manning are included above the profiles. In this instance, the MCC manager can see that he is losing key experienced people, and that he is already short on people. In the normal course of the acquisition process, the manager could expect to get novices that would enter the experience profile at the low end of the scale. If he corrects his initial manning deficiency and his expected losses with this type of acquisition, he easily see that the inexperienced end of the experience profile will become very heavy. He must do something to acquire experienced people if he is to avoid this situation.

POS: MCC     RANKS: ALL     FUNCTION: EXPERIENCE PROJECTIONS

| POSITION | | MANNING PROFILE | | |
|---|---|---|---|---|

EXPERIENCE LEVEL HISTOGRAMS

# IN EXPERIENCE GROUP

EXPERIENCE LEVEL GROUPINGS

1989   1990   1991   1992   1993

| Help F1 | Notepad F2 | Hookbook F3 | Assumptions F4 | Prior Screen F5 | Main Menu F6 | Print F7 | Quit F10 |
|---|---|---|---|---|---|---|---|
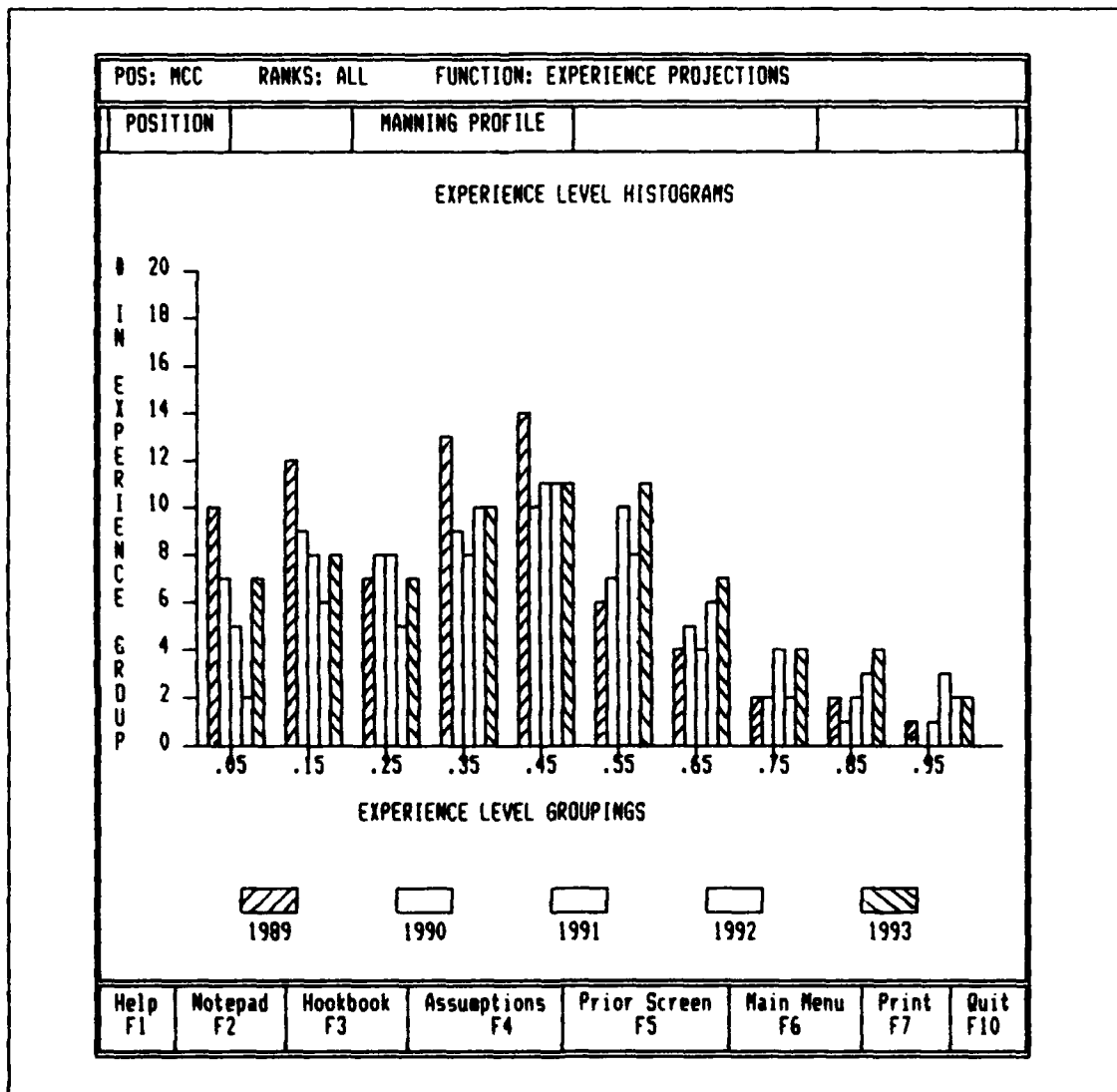
Figure 18 - MCC Experience Profile Projections

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This is the experience profiling screen for evaluating the long term impact of the acquisitions that the manager plans for the five year PFT cycle.

The experience level projections are driven from the scheduling entries that the manager makes during his "what-if" examination of acquisition scheduling options (see the next storyboard). His control of numbers of people acquired, their experience, when they are acquired, and his suggested control of factors that impact how a position loses people all impact the projection.

In this instance, the manager was looking at MCCs. The left most bar in each experience group is for the current year (1989 in this instance). Looking across the different groups at the left most bar indicates that the MCC position is heavy on inexperience people. The right most bar gives the profile after five years if the managers acquisition plan is followed. In this instance, experience for the position is distributed more evenly across the groups, the number of people in the three most experienced groups has doubled, and the average experience of the crew position has increased.

**Scheduling Acquisitions**

**(and Mid-level Assessments of Crew Position Status)**
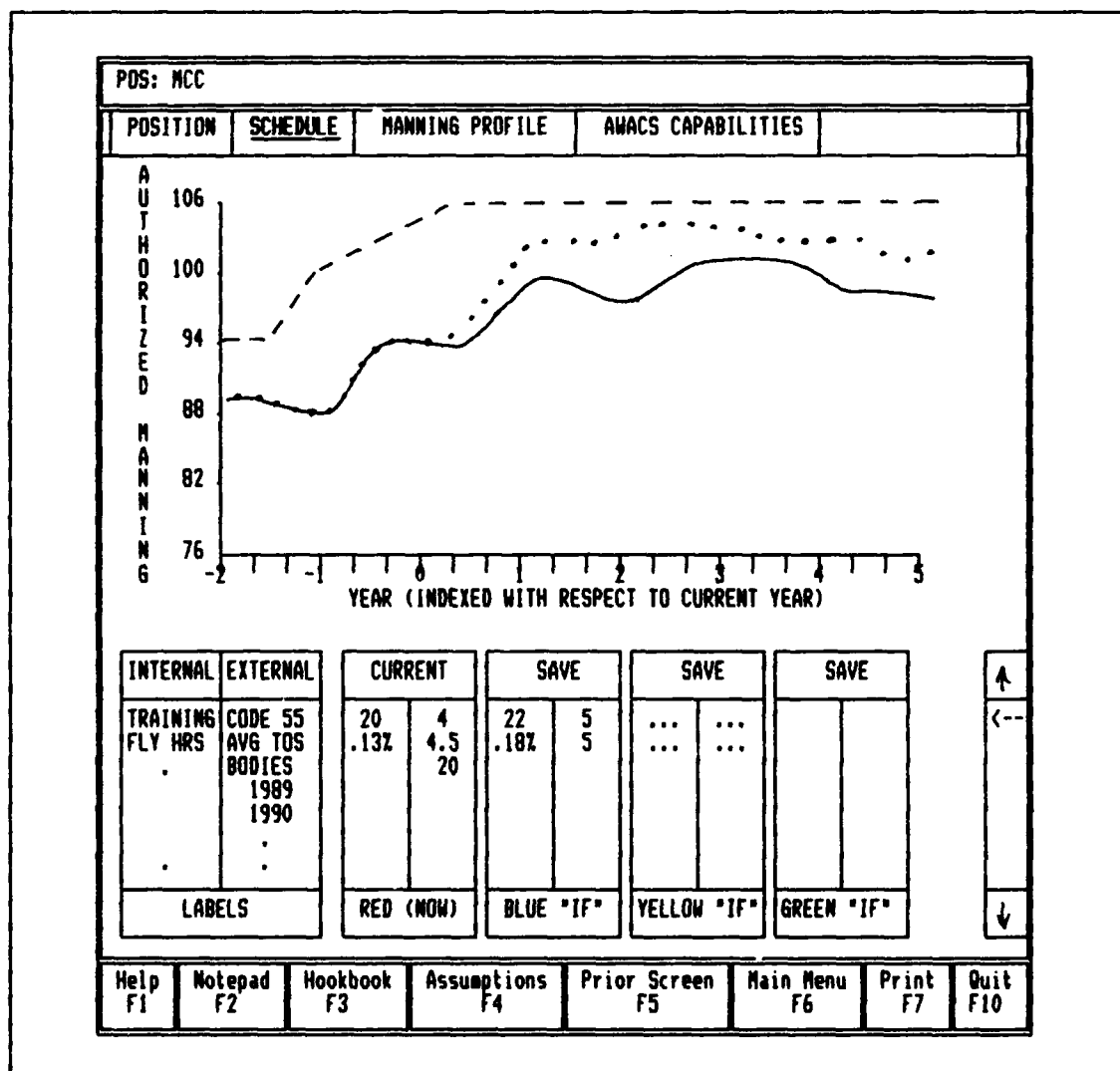
Figure 19 - Scheduling Acquisitions

Selecting SCHEDULE runs a model that plots projected manning based on current manning and acquisition policy against the planned requirements derived from FORCE STRUCTURE considerations. The requirements are in black and the current projections are in red. Levels for all current policy parameters are shown in the parameter box labeled "RED (NOW)".

A table of labels for the parameters that quantify policy positions is provided, along with a corresponding table of current values. The parameters are broken into two categories, internal and external. The internal policies are things that the 28 Air Division has control over, and the external policies are those whose change would require concurrence from outside agencies, such as TAC and MPC. As examples, the 28 Air Division has some control over how it allocates flying hour budgets and has some flexibility in how many people it can train in each crew position each year. However, MPC controls the length of the CODE 55 incurred for training, and also determines the average tour length through its PCS actions. The breakout is provided so the user knows which parameters he has the most control over.

The parameters that appear in the boxes are chosen to fit at least one of three criteria. First, they can be things that impact acquisition capabilities in some way (such as training capacity that limits how many people can be bought in a year). Second, they can be things that will alter demand for personnel (such as Code 55s, which tend to impact the average time in AWACS). Third, they can be things that impact

experience of the crew force (such as number of acquired bodies in a given year with some specified experience score). (Actually, it is necessary that some of the parameters be directly related to the factors that the experience scoring model uses to produce scores. There must be some mechanism between the scheduling process and the experience projections that allows individual experience to be incremented as time goes by).

Multiple "what-if" tables are provided to allow the user to make comparisons among various settings of the parameters. For the current screen, assume that the current training structure is set up to train 20 CDMTs a year and that they incur a 4 year CODE 55 after training. The user can look at the impact of changing these values to 22 and 5 respectively, and observe the impact on the manning chart. (The parameters can be scrolled and are synchronized across the boxes to facilitate comparison of the parameter values for a given plot). The objective is for the user to come up with an achievable set of parameters that cause the projection line to match the requirement line as nearly as possible.

Each of the "what-if" boxes is plotted in its own color; a new box will be entered when the SAVE command of the current box is selected. Previously saved boxes can be re-entered by backing up through the boxes using the Prior Screen (F5) command.

While this screen's operations is to schedule acquisitions, total manning is not the whole picture. Therefore, the MANNING PROFILE and AWACS CAPABILITIES menu options are available to examine the impact of changing parameters. Selecting the AWACS CAPABILITIES option will drop a window over the graph produced by SCHEDULE that contains the same capabilities graph previously described, with plots for the CURRENT box and any "what-if" boxes with changed parameters in them. Selection of the MANNING PROFILE option from within SCHEDULE will drop a window over the current plots and contain a line graph of the SCHEDULE and AWACS CAPABILITIES format. The graph will indicate a reference "average desired experience level" line for the crew position, and display the plots for the CURRENT box parameters and any "what-if" box parameters that have been saved.

By assessing his choices graphically with direct comparison of the results of his choices, the user can arrive at a "good" answer, and support it. He knows what he has considered, and has built in documentation showing the results of his various choices. He also has quantitative estimations of the consequences of any parameter value forced on him from outside the Division, e.g., TAC decides to buy only 4 new CDMTs for a given year.

Systems Operations Impacts

(End-game Assessments of Acquisition Strategies)
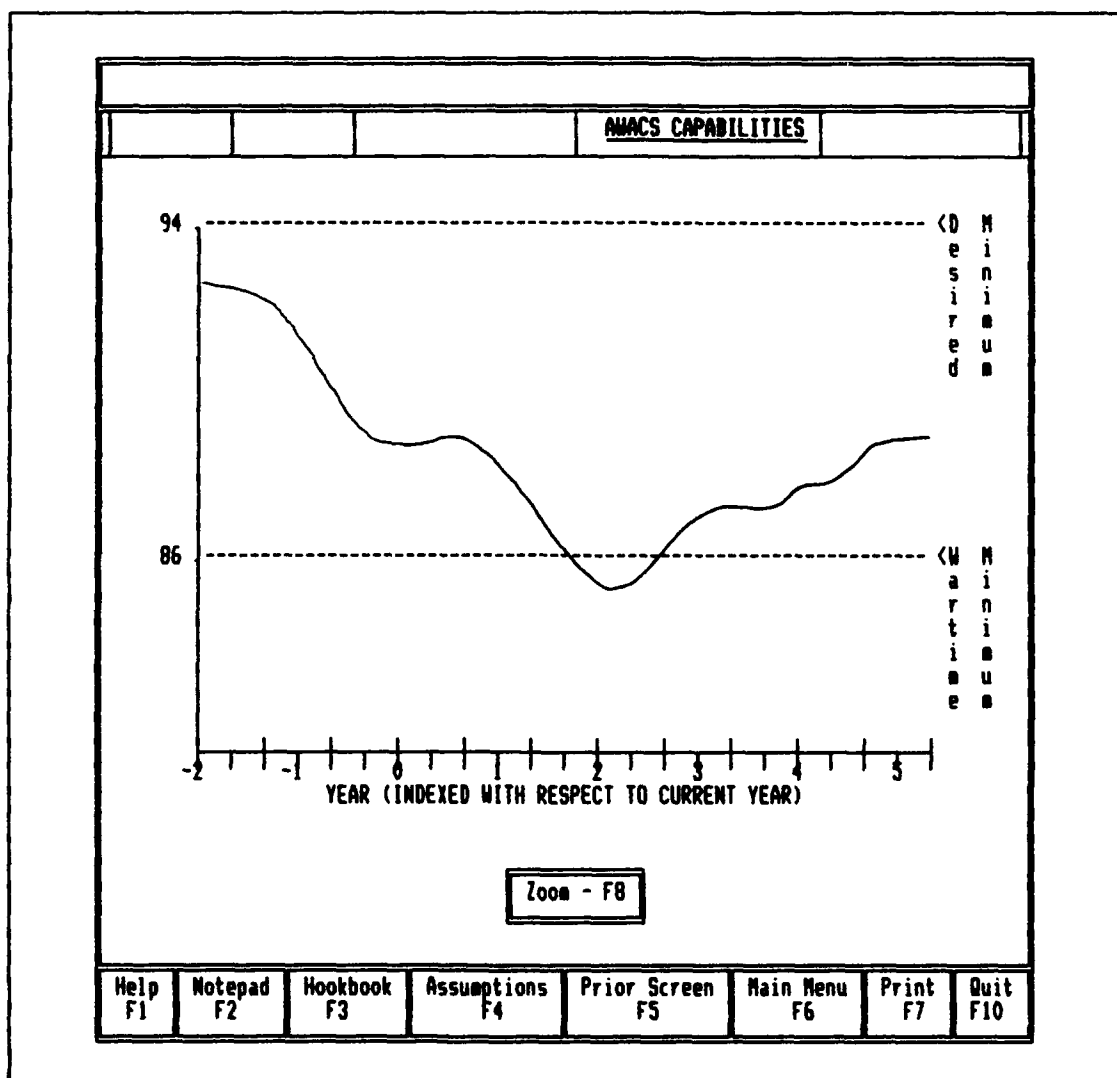
Figure 20 - High Level Capabilities Assessment

Selection of AWACS CAPABILITIES produces a graphic plot of AWACS mission capability as affected by personnel issues. The plot is from the current date minus 2 year to current date plus 5 years (1 long range acquisition cycle). The capability factor is plotted relative to two reference levels (scaled to 100): desired day to day minimum capability, and minimum war fighting capability for effective operation. The plot is driven by a Multi-Criteria Optimization model that accesses the personnel database. Major inputs are crew experience profiles and absolute manning levels.

The impact of personnel issues on AWACS capabilities are of paramount importance. This combined assessment of manning levels and experience provides an important tool to structure new accessions. Quantity may have to be balanced by quality; re-acquiring of previous AWACS personnel may be the only solution to a decrease in capability caused by a lack of experience or a shortage of bodies. The timing of acquiring new bodies or attempting to re-acquire old ones will be critical in balancing capability shortfalls that occur in the future due to current personnel managements. The AWACS CAPABILITIES graphics provides a means for identifying the shortfalls and the specific causes.

The memory aid bar indicates there is no crew position filter set. If a filter has been previously specified, selection of AWACS CAPABILITIES disables the filter.

Systems capabilities is a composite estimation of ability to perform a
mission. No other menu options are available from this command.
A zoom feature is supported to allow for increased resolution in a
selected area. This facilitates examination of critical areas in the
future. Selecting the Zoom command will position cross-hair on the
screen that can be positioned with mouse or cursors. A special key to
execute Zoom is provided; this is as a courtesy to facilitate execution
of a command from the live window. It is also a reminder that there is
more to this screen than the presented graph. All commands offered as
sinale commands on the live screen can be executed by clicking or
striking the return key.

Figure 21 - Changing Capabilities Assessment Resolution

Selection of the Zoom feature placed cross-hairs on the screen. After positioning, clicking, hitting return, or hitting F8 executes the zoom at the specified point.

F8 option is again the "hot key" from the live screen. Again, all commands offered as single commands on the live screen can be executed by clicking or striking the return key.
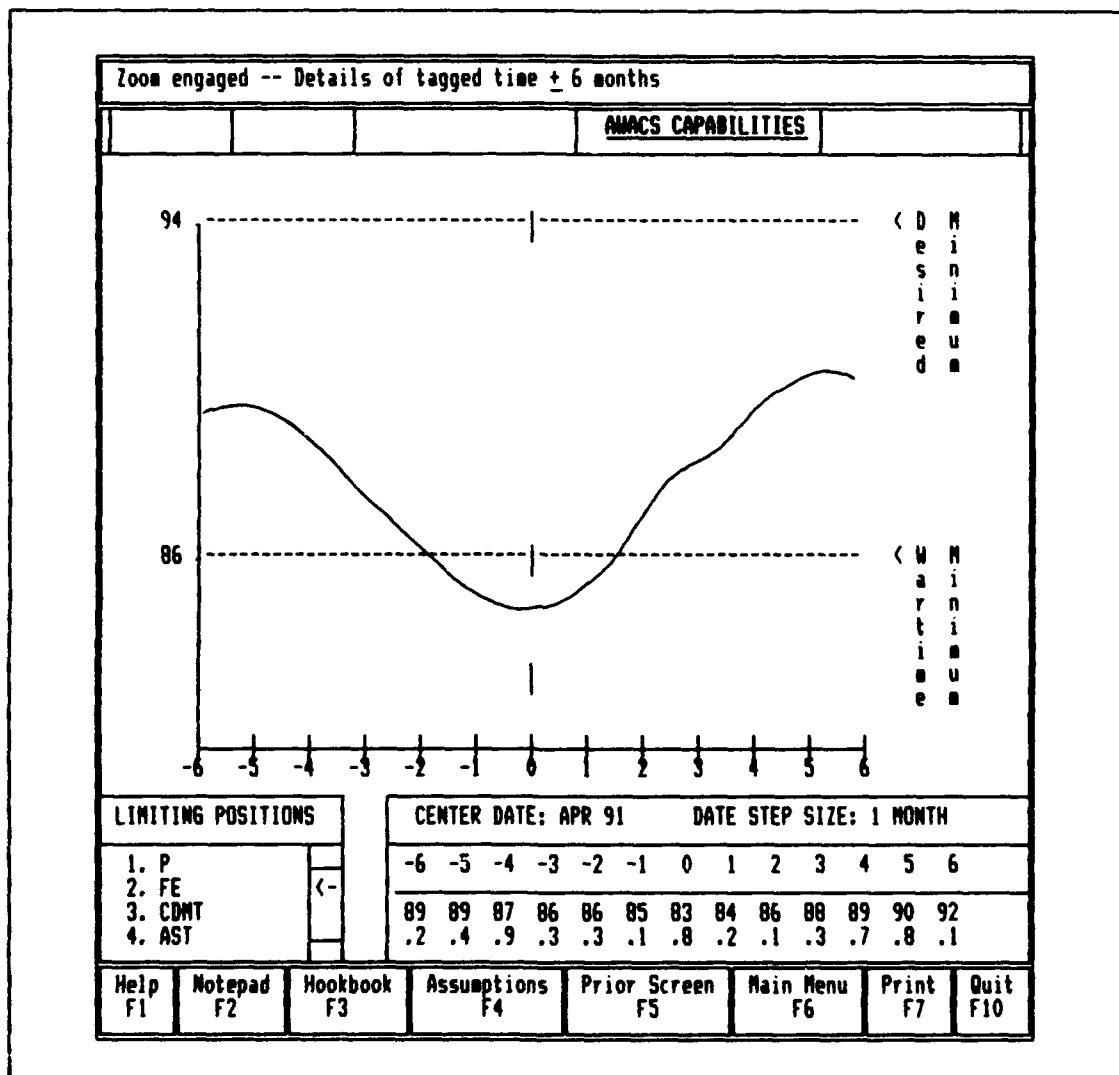
Figure 22 - Detailed Capabilities Assessment

The screen displayed as a result of the Zoom sequence show a roughly 7 to 1 increase in date resolution on a re-scaled graph. The display centers the selected point from the low resolution graph on the new plot, indicated by vertical tics crossing the reference lines at the 0 coordinate. The plot is shown for six months on each side of the selected point.

The fact that the user is viewing capabilities at increased resolution is provided as a reminder on the memory aid bar.

Discrete values for each month are provided in a table to remove interpolation problems. Integer parts are place on one line and fractional parts on another. This improves readability of the screen, and also speeds up scanning for trends, ignoring fine detail.

Finally a table is provided, showing the four crew positions that the model driving the assessment being plotted is most sensitive to at the current point. (Sensitive to with respect to improvement). The crew positions are rank ordered.

Detailed assessment of the impact of specific crew positions is available at this point by selecting the position of interest from the "LIMITING POSITIONS" list.

Low level Supporting Information

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```
                                                    FORCE STRUCTURE
```

| | 1989 | 1991 | 1996 | 2000 | | BASE |
|---|---|---|---|---|---|---|
| PAA | | | | +3 | | 29 |
| CREWS | | | +.2 | +.2 | | 1.7 |
| POS | AIRCRAFT MODIFICATIONS | | | | | |

| POS | 1989 | 1991 | 1996 | 2000 | | BASE | |
|---|---|---|---|---|---|---|---|
| | | 30 -- 35 | | | | | ↑ |
| SD | | +1 | | | | 1 | |
| WD | | +2 | | | | 3 | |
| ASO | | | | | | 1 | |
| AST | | +2 | | | | 2 | |
| ART | | | | | | 2 | |
| CDMT | | | | | | 1 | <-- |
| CSO | | +1 | | | | 1 | |
| CT | | | | | | 1 | ↓ |

| POS | ORGANIZATIONAL CHANGES | | | | | |
|---|---|---|---|---|---|---|

| POS | 1989 | 1991 | 1996 | 2000 | | BASE | |
|---|---|---|---|---|---|---|---|
| | ADD 962 | | | | | | ↑ |
| P | +2 | | | | | 18 | <-- |
| NAV | +1 | | | | | 14 | |
| FE | +1 | | | | | 3 | |
| MCC | +1 | | | | | 28 | |
| SD | | | | | | 9 | |
| WD | | | | | | 8 | |
| ASO | | | | | | 23 | ↓ |

| Help F1 | Notepad F2 | Hookbook F3 | Assumptions F4 | Prior Screen F5 | Main Menu F6 | Print F7 | Quit F10 |
|---|---|---|---|---|---|---|---|

Figure 23 - AWACS Force Structure Representation

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The FORCE STRUCTURE option is selected to view the prime factors that drive changes in AWACS manning. Theses are:

PAA: Primary Assigned Aircraft -- The number of aircraft used in conducting AWACS mission. Purchases of new aircraft would require more manning.

CREWS: Number of crews assigned for each PAA. Changes in AWACS mission could warrant changes in the number of crews assigned to each aircraft.

AIRCRAFT MODIFICATIONS: Changes in AWACS mission can require changes in the crew structure. As an example, the block 30-35 mod on the E-3 will call for more WDs and ASTs to enhance weapons control and surveillance capabilities.

ORGANIZATIONAL CHANGES: Structural changes in the 28 Air Division may impact manning. The creation of the 962 AWAC Squadron increased the overhead for certain crew positions to provide the squadron staff.

The memory aid bar indicates there is no crew position filter set. The POSITION command is present, indicating FORCE STRUCTURE can be filtered if desired. (If selected, the position pop down menu appears). If a position is selected, the PAA and CREW elements remain unchanged. Only the crew position of interest would appear under AIRCRAFT MODIFICATIONS and ORGANIZATIONAL CHANGES.

The AIRCRAFT MODIFICATIONS and ORGANIZATIONAL CHANGES sub-charts have scroll bars to scroll the crew position charts, if necessary. Point and

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click (mouse or cursor/return) on the up or down arrows to scroll in the
indicated direction, with the current position in the list being
indicated by the left pointing arrow. (As in MacIntosh operations).
The sub-chart heading will remain to indicate which sub-chart is which.

The BASE column holds the appropriate values for the current force
structure. In the AIRCRAFT MODIFICATIONS sub-chart, the number for each
position per crew will be displayed. In the ORGANIZATIONAL CHANGES
sub-chart, current overhead in each position will be displayed. Crew
positions will be coordinated across all columns and scrolling
synchronized.

Columns are only provided for years in which changes occur. Only the
change from the previous level is indicated, and changes are cumulative
across the columns. (For example, a change in CREW is indicated for
1996 and 2000. With BASE indicating a BASE CREW of 1.7 per aircraft,
the figure indicates a force structure of 1.9 crew/aircraft for 1996 and
2.1 for 2000). Change, and not level, is shown because the intent of
this chart is to indicate what changes are going to occur and when they
will occur.

No operations occur under FORCE STRUCTURE. It is provided as a means of
representing critical background information.

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```
POS: CDMT

┌──────────┬──────────────────────────┬──────────────┬──────────┐
│ POSITION │        MANNING PROFILE   │              │          │
│          │                          │              │          │
│          │  Rank filters            │              │          │
│          │  Losses                  │              │          │
│          │  Gains                   │              │          │
│          │  All                     │              │          │
│          │  Experience              │              │          │
│          │    Current               │              │          │
│          │    Projections           │              │          │
```

Help      Notepad    Hookbook   Assumptions   Prior Screen   Main Menu   Print    Quit
F1        F2         F3         F4            F5             F6          F7       F10

Figure 24 -  Manning Profile Sub-options
```

```
POS: CDMT

┌──────────┬──────────────────────────┬──────────────┬──────────┐
│ POSITION │        MANNING PROFILE   │              │          │
│          │                          │              │          │
│          │  Rank filters            │              │          │
│          │ ┌──────────────────────────────────┐    │          │
│          │ G│ E │ 2 │ 3 │ 4 │ 5 │ 6 │ 7 │ 8 │ 9 │  │          │
│          │ A├──────────────────────────────────┤    │          │
│          │ E│  Highlight ranks you want to see.│    │          │
│          │  │  Select either a single rank or a│    │          │
│          │  │  continuous set of ranks.        │    │          │
│          │  └──────────────────────────────────┘    │          │
```

Help      Notepad    Hookbook   Assumptions   Prior Screen   Main Menu   Print    Quit
F1        F2         F3         F4            F5             F6          F7       F10

Figure 25 - Selecting a Rank Filter
```

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The MANNING PROFILE features allow the user to explore different aspects of his problem at the database level. He can look at the data and make direct correlations with the people he knows. He can look directly at short term losses and determine how well his known gains balance losses. Support is provided to look at all people in the database. Finally, experience profiles are provided so the user has a feel for some of the factors involved in the AWACS CAPABILITIES assessment. Selection of the MANNING PROFILE option drops a pop down menu of sub-options.

Basic descriptions of the sub-options are given on as part of the help system, (accessed via F1, and shown as the last storyboard). The position filter can be set from within the MANNING PROFILE command, as indicated on the menu bar. In this case, the filter is currently set to CDMT, as indicated on the memory aid bar.

One of the primary purposes of this section of the support system is to provide the user with basic data, in a structured environment, to allow him to exercise his intuition. His intuition may become fine-tuned in the process of using the system, or it may prove to be better than the models driving the system, which should prompt him to make hookbook entries concerning his perception of system deficiencies.

Selecting 'Rank filters' causes a pop down rank selection area to appear. Rank is selected by clicking and dragging with a mouse or by placing the cursor on the desired end points of the range and hitting

return. (Hitting return twice selects the single rank designated by the cursor). The ranks displayed in the selection area are keyed by the selected crew position. (The rank filter is the deepest branch of the decision command tree, and is only three levels deep).

Rank filtering is provided to allow the user to break the crew position being examined into smaller chunks that have special significance to him. Rank appears to be the best discriminator, since it is linked to responsibility level, time in service, experience, and special areas of qualification within the crew position.

The capability of selecting a range of ranks is provide to allow resolution flexibility; looking at the top three may be sufficient for some judgments, while the crew positions status with respect to E-9 may be critical in others.

```
POS: CDMT      RANKS:  E7 - E9    FUNCTION: LOSSES

POSITION              MANNING PROFILE

                                   EXPERIENCE   LOSS
     RANK              NAME          FACTOR      DATE

     ...               ...            ...        ...        ↑
     ...               ...            ...        ...       <--
     ...               ...            ...        ...
     ...               ...            ...        ...
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     ...               ...            ...        ...
     ...               ...            ...        ...
     ...               ...            ...        ...
                                                           ↓

  Help   Notepad  Hookbook  Assumptions  Prior Screen  Main Menu  Print  Quit
  F1     F2       F3        F4           F5            F6         F7     F10
```

Figure 26 - A Low Level Data Representation

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This is a representative screen for the GAINS and LOSSES options of the MANNING PROFILE choice. Both of these options require a crew position to be selected, and are two of the three mentioned from the opening screen description. Position can be changed, but the "All" option will not appear on the menu.

This screen is displayed as a loss screen. The memory aid bar reminds the user that he is looking at CDMTs in the grades of E7 to E9 who are projected as losses.

A scroll bar is provided to scroll through the list. Point and click (mouse or cursor/return) on the up or down arrows to scroll in the indicated direction, with the current position in the list being indicated by the left pointing arrow. (As in MacIntosh operations). The sub-chart heading will remain to stationary during scrolling. The roster is indexed on RANK then LOSS DATE and then NAME. An indexing command can be supported and implemented through a pop-up priority selection table.

## Appendix C

## Hookbook Entries

This appendix contains the aggregated contents of the hookbook entries made during the research effort. The IDEA portions of the individual hookbook entries have been grouped by the system's adaptation areas that were evident to the author.

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RESOLUTION — DON'T BECOME CONSUMED WITH BUILDING HIGH RESOLUTION
MODELS. CERTAINLY, AT THE BEGINNING, LOOKING AT NEEDS
BASE ON AN ANNUAL TIME FRAME IS ADEQUATE.

RESOLUTION — SUPPORT CHANGES IN THE CURRENT YEAR RESULTING FROM
QUARTERLY UPDATED MEETINGS.

RESOLUTION — START LOOKING AT TRAINING FLOW AND THE PROBLEMS IT
INTRODUCES IN THE SYSTEM. THESE TYPES OF FACTORS WILL
FOR AN INCREASE IN RESOLUTION, SINCE TRAINING ISN'T
GENERALLY UNIFORM ACROSS A YEAR.

RESOLUTION — ANNUAL SPECIFICATIONS INITIALLY, WITH ASSUMPTIONS THAT
TRAINING IS UNIFORM ACROSS THE YEAR (NOT TRUE, BUT IN THE
SCOPE OF THIS PROBLEM AT THE INITIAL STAGES, THE
VARIATIONS IN MANNING AND EXPERIENCE CAUSED BY NON-
UNIFORM TRAINING THROUGH THE YEAR ARE INSIGNIFICANT WHEN
COMPARED TO THE PROBLEMS CAUSED BY MANAGERS NOT LOOKING
AT THE ACQUISITION PROCESS IN ANY DETAIL BEYOND THE
IMMEDIATE YEAR'S NEEDS.

MODELS — THREE BIGGIES — EXPERIENCE — MANNING LEVEL —
CAPABILITIES

MODELS — EACH OF THE THREE MAJOR MODEL HAVE TO BE ABLE TO LOOK AT
"NOW" AND PROJECT TO THE FUTURE

MODELS — IN ORDER TO MAKE PROJECTIONS, THE MODELS ARE GOING TO
HAVE TO INTERACT

MODELS — PERSONNEL ISSUES ARE "SOFT" ISSUES. IF MCDM
METHODOLOGIES ARE USED IN THE MODEL DEVELOPMENT, THE
MODELS MAY BENEFIT FROM A STATISTICAL VALIDATION OF THE
VALUES THEY PRODUCE.

MODELS — THE CAPABILITIES MODEL CAN CERTAINLY BE EXPRESSED AS A
MULTI-CRITERIA OPTIMIZATION PROBLEM (OR SOME OTHER FORM
OF MCDM MODEL). IT IS CONCERNED WITH BALANCING
CONFLICTING OBJECTIVES — MANNING LEVEL AND EXPERIENCE,
FOR EACH CREW FORCE — WHERE ARE RESOURCES TO BE
ALLOCATED.

MODELS — CAPABILITIES NEEDS TO BE ASSESSED AGAINST MULTIPLE
EXPERIENCE CRITERIA. MEAN EXPERIENCE IS NOT SUFFICIENT,
SOME DISTRIBUTION MEASURES WILL ALSO BE NEEDED.

MODELS — OPPS!! SCHNEIDER'S DEPARTURE MODELS ARE NOT GOING TO BE
ADEQUATE. DEPARTURES ARE GOING TO HAVE TO BE BROKEN OUT
INTO CATEGORIES THAT CAN BE CORRELATED TO EXPERIENCE IF
EXPERIENCE PROJECTIONS ARE GOING TO BE MADE.

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MODELS —    ASSUMPTIONS:  PROGRESSION IN EXPERIENCE WILL BE BASED ON
            ALL PERSONNEL IN THE POSITION DOING THINGS THROUGH TIME,
            SUCH AS MEETING THEIR MINIMUM QUALIFICATION FLYING
            HOUR/MISSIONS GOALS.  ANY EXCESS FLYING HOURS WILL BE
            APPORTIONED UNIFORMLY AMONG THE CREW FORCE IN THIS CASE.
            THIS WOULD BE A MODELING ASSUMPTION, AND NEEDS TO BE
            STATED AS SUCH.

MODELS —    ASSUMPTIONS:  MODELS MAKE LOTS OF ASSUMPTIONS -- DOCUMENT
            THEM.

MODELS —    MODELS ARE GOING TO HAVE TO HANDLE LOTS OF TRICK
            QUESTIONS TO MAKE PROJECTIONS.  TRANSITIONS ACROSS CLASS
            BOUNDARIES WILL HAVE TO BE HANDLED AND DOCUMENTED.

MODELS —    DISCRIMINANT ANALYSIS BEARS EXAMINATION IN THE FUTURE,
            BUT NOT NOW.  UNTIL THE SYSTEM IS CHANGED ENOUGH THAT
            THERE IS SOME PROBABILITY OF RECOVERING PERSONNEL FROM
            THE AIR FORCE MANNING POOL, PRIORS FOR THE DISCRIMINANT
            FUNCTION CANNOT BE ESTIMATED.  (ACTUALLY 0 CURRENTLY,
            WHICH DOESN'T HELP DISCRIMINATE).

MODELS —    ARTIFICIAL INTELLIGENCE MODELS ARE NOT A PLAYER IN THIS
            SYSTEM UNTIL IT, AND THE USERS MATURE QUITE A BIT.  AI IS
            A POSSIBILITY AT SOME FUTURE DATE FOR SPEEDING UP THE
            "WHAT-IF" CYCLE IN THE SCHEDULING OPTION.

MODELS —    A GOOD EXPERIENCE MODEL -- PROBABILITY OF BEING AN
            INSTRUCTOR / STAN EVALER.  ASSUMPTION -- THESE PEOPLE ARE
            AT THE HIGH END OF THE EXPERTISE SCALE FOR THE CREW
            POSITION.

MODELS —    QUESTIONS -- ANSWERS REQUIRE STATEMENT OF ASSUMPTIONS
            1.  WHAT ARE THE MECHANISMS FOR PREDICTING LOSSES IN EACH
                CREW POSITION
                - RATES BY RANK -- SEPARATIONS AND LOSSES -- BASED
                  ON AWACS DATA -- OR IS AIR FORCE WIDE DATA
                  SUFFICIENT UNTIL AWACS DATA IS DEVELOPED?
                - RATES BY YEARS OF SERVICE ??
                - IMPACT OF THINGS LIKE FORCE REDUCTION

            2.  SAME FOR GAINS --  PROJECTING PROMOTIONS IS IMPORTANT
                IF LOSS RATES ARE BY GRADE.

MODELS —    LOOK AT THE RESULTS!!  JUST BECAUSE THE MODELS SAY
            SOMETHING, DON'T TAKE IT AT FACE VALUE.  USING
            INSTRUCTORS AS AN EXPERT BASELINE COULD REALLY GIVE
            SCREWY RESULTS IN A REGRESSION IF A) BEING AN INSTRUCTOR
            IS VIEWED AS A PROMOTION POSITION, AND B) YOU DON'T CAP
            FACTORS SUCH AS YEARS OF SERVICE FOR PASSED OVER
            OFFICERS.

MODELS --       MAKE MODELS ABLE TO RECOMMEND OPTIMUM STRATEGIES, THEN
                RESPOND TO "WHAT-IFS" FROM THAT INITIAL STARTING POINT ?
                DO I REALLY WANT TO IMPINGE ON THE USERS WHAT IF
                EXPLORATION ?  HOW DO YOU KEY THE USER TO START HIS
                PROCESS?  THIS AT LEAST GIVES HIM A STARTING POINT
                BESIDES A BLANK SCREEN.

MODELS --       POSSIBLE PARAMETERS FOR SCHEDULING SCREEN
                        CODE 55
                        AVG ON STATION
                        ACCESSION SOURCES
                        EDUCATIONS
                        TRAINING
                        FLYING HOURS
                        NEW/USED SPLITS

                THESE ARE JUST ODD THOUGHTS ON POSSIBLE PARAMETERS THAT
                LEND THEMSELVES TO MANIPULATION BY THE USER TO ARRIVE AT
                A DECISION.  THESE ARE THE PARAMETERS THAT VARY THE
                MODELS OUTPUTS.  FINAL DETERMINATION OF APPROPRIATE
                PARAMETERS WILL HAVE TO BE BASED ON THE FACTORS THAT GO
                INTO QUANTIFYING EXPERIENCE.  THE DATA IS GOING TO DECIDE
                THIS.  PARAMETERS WILL HAVE TO HAVE SOME DIRECT
                CORRELATION TO THE INPUTS TO THE MODELS.

MODELS --       OTHER PARAMETERS -- CONCEIVABLE MORE IMPORTANT THAN MAJOR
                PARAMETERS ABOVE BUT THEY WOULD REQUIRE POLICY CHANGES
                OUTSIDE OF THE MANAGERS SCOPE OF OPERATION
                        CODE 55
                        AVG TOUR LENGTH
                        ACCESSION SOURCES
                        MISSIONS FLOWN

MODELS --       DON'T FORGET DOS ETC AS INPUTS TO LOSS CALCULATIONS MAKE
                SURE ALL DRIVERS FOR GAINS AND LOSSES ARE
                CONSIDERED.

MODELS --       MAJOR PARAMETERS TO BE MANIPULATED BY CURRENT MANAGER --
                BODIES AND TIMING.

MODELS --       PRINCIPLE COMPONENTS ANALYSIS COULD HELP SCREEN THE
                POSSIBLE FACTORS TO BE CONSIDERED IN THE EXPERIENCE
                ANALYSIS.  THIS COULD SIGNIFICANTLY SIMPLIFY DATABASE
                ACCESS ISSUES.

EXTENSIONS --   GRAPHS PROVIDE QUANTITATIVE AMMO IN BARGAINING WITH
                MPC/TAC CONSEQUENCES ARE IMMEDIATELY DISCERNABLE.  OCCURS
                TO ME THAT THESE GRAPHICAL PRESENTATIONS CAN PROBABLY BE
                UNDERSTOOD BY TAC AND AFMPC -- GOOD AMMO.  THIS CAN ALSO
                PROBABLY BE CONSIDERED A CONTROL MECHANISM.

EXTENSIONS -- AN EXTENSION OF THE USE OF THIS SYSTEM WOULD BE TO
IDENTIFY INDIVIDUALS WHO ARE "BEHIND THE CURVE" AND FLY
THEM MORE OFTEN.

EXTENSIONS -- THERE IS A DANGER THAT THIS SYSTEM COULD BECOME A SQUARE
TO BE FILLED. HOW TO AVOID THIS, IF IT IS SOMETHING TO
BE AVOIDED. IF FILLING THE SQUARES BECOMES THE GOAL, AND
IT IMPROVES "EXPERIENCE", IS THIS A PROBLEM. THE
VULNERABILITY OF THE SYSTEM BEING GAMED FOR OTHER
PURPOSES IS VERY DEPENDENT ON THE FACTORS CHOSEN TO
INDICATE EXPERIENCE. FOR FACTORS SUCH AS TIME IN
SERVICE, THERE IS NOTHING THE MEMBER CAN DO ABOUT ITS
IMPACT ON HIS EXPERIENCE SCORE.

EXTENSIONS -- EXPERIENCE SCORES COULD BE USED TO HELP IDENTIFY
CANDIDATES FOR "SPECIAL JOBS" SUCH AS INSTRUCTOR, STAN
EVAL OR SCHOOL ATTENDANCE. THIS COULD ALSO BE USED AS A
MODEL VALIDATION TOOL, SINCE CONSISTENT DISAGREEMENT MAY
INDICATE EXPERIENCE IS BEING SCORED WRONG.

PRESENTATION - SPLIT SCREEN FOR CHARTS -- ENCOURAGE DIRECT COMPARISONS,
DON'T HAVE TO GO TO PRINTER IF POSSIBLE -- PARTICULARLY
FOR EXPERIENCE AND MANNING

PRESENTATION - TOGGLE ON YEAR TO BLOWUP PROFILE IN 1 YEAR PERIODS POP UP
TABLE OF MIN/MAX VALUES, AVG, STD, OTHER PERTINENT DATA
TO CLARIFY/SUPPORT GRAPHICS DISPLAYS. CLOSE LOOKS AT
DATA WILL HAVE TO BE SUPPORTED, AND INTERPOLATION
PROBLEMS SHOULD BE AVOIDED.
ADD TABLES OF CRITICAL INFORMATION KEYED TO GRAPHS.

PRESENTATION - HOW TO DISPLAY EXPERIENCE DISTRIBUTION ON PROJECTIONS --
-- HAVE A BAND INSTEAD OF A LINE TO ACCOUNT FOR VAR ABOUT
AVERAGE VALUE ??

PRESENTATION - PERHAPS A COLOR GRADIENT IN THE LINE IS MORE EFFECTIVE
THAN A BAND. MAYBE A SIMPLE GREEN TO YELLOW TO RED TO
SIGNAL STRUCTURAL HEALTH OF THE CREW PROFILE

PRESENTATION - DISPLAY EXPERIENCE AS A HISTOGRAM -- PROJECTIONS BUILD
HISTOGRAMS THAT CAN BE COMPARED ACROSS YEARS

PRESENTATION - IF NECESSARY, INCREASE THE VERTICAL RESOLUTION ON THE
HISTOGRAMS BY STARTING THE SCALE AT SOME VALUE OTHER THAN
0. FOR THE FEW BARS THAT ARE SHORTER THAN THE BASE
VALUE, WRITE THE MARGINAL AMOUNT ABOVE THE BAR.

PRESENTATION --A POSSIBLE REFINEMENT OF THE EXPERIENCE LEVEL
PRESENTATION IS A GO-NO GO INDICATOR FOR THE DISTRIBUTION
PARAMETERS (KIRTOSIS AND SKEWNESS IN PARTICULAR) THAT
INDICATES WHETHER THE CREW PROFILE IN A GIVEN YEAR IS
GOOD. FOR THE CURRENT WORK, A GRAPHICAL LOOK AT THE
DISTRIBUTION IS ALL THAT WILL BE PRESENTED.

PRESENTATION --SUPPLYING REFERENCES FOR THE MODELING RESULTS TO BE
MEASURE AGAINST CAN BE TRICKY. FOR BODIES, IT IS EASY
SINCE THE REFERENCE IS JUST THE AUTHORIZED MANNING LEVEL.
FOR EXPERIENCE, THE REFERENCE WILL HAVE TO BE BUILT SOME
HOW -- EXPERT OPINION (MADA) -- USE AUTHORIZED RANK
STRUCTURE, ASSUMING THAT RANK STRUCTURE IS HOW MPC TRIES
TO MANAGE EXPERIENCE ???

PRESENTATION - ALLOW THE USER TO EXAMINE HIS "WHAT-IFS" ON THE SAME
SCREEN. USE MULTIPLE WINDOWS FOR THE USER TO LOAD
DIFFERENT PARAMETER VALUES INTO, AND DRAW THE LINE FOR
EACH WINDOW ON A COMMON GRAPH. COLOR CODE LINES ON THE
GRAPH WITH THE WINDOW IT CORRESPONDS TO. THIS ALLOWS THE
USER TO KEEP CLEAR WHAT HE HAS CONSIDERED AND HOW THE
RESULTS COMPARE.

DESIGN -- THE SCHEDULING PROCESS REQUIRES MORE THAN A SIMPLE
CONSIDERATION OF MANNING LEVEL IN TERMS OF BODIES.
EXPERIENCE HAS TO BE OBSERVABLE AT THE SAME TIME.

DESIGN -- PARADIGM -- MATCH LINES FOR DECISION ---- PRE-AFIT
THOUGHT ON HOW TO BEST MAKE THE DECISION BEING SUPPORTED.
KEEP IT SIMPLE!!! THIS ENTRY ALSO PROPERLY FALLS UNDER
OPERATION.

DESIGN -- PARADIGM IS CRITICAL

DESIGN -- DESIGN TOOLS APPEAR TO BE IN SHORT (NON-EXISTENT ?)
SUPPLY. WHY? THEY ARE NEEDED, SO WHY AREN'T THEY
AVAILABLE.

DESIGN -- STORYBOARDING IN A WORD PROCESSOR IS A HORRIBLE
EXPERIENCE AGAIN, WHY AREN'T THERE GOOD TOOLS.
STORYBOARDING TOOLS THAT BUILD INTERACTIVE STORYBOARDS
SHOULD BE AVAILABLE !!

DESIGN -- DSS IS DEAD IF SOMEBODY DOESN'T BUILD AN EFFECTIVE DSS
GENERATOR. WRITING CODE FROM SCRATCH TAKES TO LONG.
WITHOUT A GENERATOR, AN OUTSTANDING SET OF TOOLS WILL
HAVE TO BE BUILT IN ADVANCE OF ATTEMPTING TO DESIGN A
DSS.

DESIGN -- REGARDLESS OF HOW HARD IT IS TO CODE, SPREADSHEET
ENVIRONMENTS ARE A STOP GAP AT BEST. MACROS ARE
INSUFFICIENT, AND BLOCK OPERATIONS ON DATABASE ELEMENTS

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ARE DIFFICULT SINCE A) FIELD NAMES MUST BE KNOW, B)
OPERATIONS ARE GENERALLY DIFFICULT TO DEFINE UNLESS THEY
ARE HARDWIRED INTO THE SPREADSHEET.


DESIGN --      QUATTRO PRO MAY BE CLOSE TO A FULLY AUTOMATED
STORYBOARDING TOOL

DESIGN --      DON'T FORGET THAT MANNING IS CYCLIC -- PAY SPECIAL
ATTENTION TO PERIODS OF HIGH ACQUISITION DEMAND;  DAMP
FLUCTUATIONS -- IF 20% OF THE CREW FORCE NEEDS TO BE
REPLACED THIS YEAR, THE SAME WILL BE TRUE IN ROUGHLY FIVE
YEARS WHEN ALL OF THE NEW BODIES PCS.  THIS "BOOM OR
BUST" CYCLE MUST BE BROUGHT UNDER CONTROL.  CURRENTLY,
THE CYCLIC NATURE OF MANNING IS IGNORED BECAUSE OF THE
SHORT TERM ORIENTATION OF THE PLANNING PROCESS.

DESIGN --      DISPLAY - 1 YEAR + 5 SCHEDULING GRAPH, NOT 10 YEARS AS
ORIGINALLY CONCEIVED -- THE CHAIN OF ASSUMPTIONS IS GOING
TO BE EXTENDED TO LONG FOR RESULTS TO HAVE ANY MEANING IN
THE 10 YEAR TIME FRAME.

CONTROL --      MAKE SELECTION OF POSITION IN SYSTEM RESPONSIVE TO FIRST
LETTER STRING FULL BLOWN COMMAND LANGUAGE TO COMPLEX FOR
US TO ACHIEVE

CONTROL --      AUTO ENTRY IN HOOK OF SCREEN FROM WHICH ENTRY IS MADE
AUTO ENTRY IN HOOK OF PROGRESSION TO SCREEN
DATE/TIME/OPERATOR STAMP IN HOOK ENTRIES

CONTROL --      ASSUMPTIONS MUST BE VISIBLE IF USER IS TO SUCCESSFULLY
NAVIGATE THROUGH A DECISION PROCESS -- ADD AN ASSUMPTIONS
BUTTON AS IN EL SHERIF

IMPLEMENTATION-WHAT IS NEEDED IS AN ENVIRONMENT THAT FOSTERS DEVELOPMENT
OF AN OPERATIONAL SYSTEM, AND THEN GENERATES THE SPECIFIC
STAND ALONE CODE TO EXECUTE ALL OF THE FUNCTIONS THAT
HAVE BEEN DEVELOPED.
UNTIL THEN, BUILD PROTOTYPES IN SOME ENVIRONMENT THAT
PROVIDES ALL OF THE NECESSARY FUNCTIONS, AND THEN
REPROGRAM, EVEN THOUGH THIS EFFECTIVELY LOOSES THE
DEVELOPER A MAJOR PART OF THE EFFORT DEVOTED TO
PROTOTYPING.

IMPLEMENTATION-REGARDLESS OF WHERE A DSS IS DESIGNED, THE IMPLEMENTED
VERSION NEEDS TO BE IN STAND ALONE CODE FOR PERFORMANCE
AND FLEXIBILITY -- WHERE IS MY DSS GENERATOR?

VALIDATION -- THE PROCESS OF REPEATEDLY OPERATING THE MODELS WITH
VARIED PARAMETERS WILL PROVIDE INSTRUCTION IN THE SYSTEMS
USE AND VALIDATION FOR THE MODELS.  OBSERVABLE
CONSEQUENCES OF PARAMETER CHANGES CAN BE CHECKED AGAINST

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THE MANAGER'S INTUITIONS, WHICH WILL MATURE AS THE SYSTEM
IS EXERCISED.

EVOLUTION -- IT MUST BE MADE CLEAR TO THE USERS THAT THE SYSTEM WILL
ONLY BE AS GOOD AS THEY MAKE IT.  USERS MUST KNOW THAT
ALL USER INPUTS ARE IMPORTANT, AND MORE, THAT AT A
MINIMUM, USER INPUT IS NECESSARY TO FINE TUNE THE MODELS
USED TO SUPPORT THEIR DECISIONS.

EVOLUTION -- AUTO ENTRY IN HOOK OF SCREEN FROM WHICH ENTRY IS MADE
AUTO ENTRY IN HOOK OF PROGRESSION TO SCREEN
DATE/TIME/OPERATOR STAMP IN HOOK ENTRIES

EVOLUTION -- ASSUMPTIONS MUST BE VISIBLE FOR EVOLUTION TO OCCUR -- ADD
AN ASSUMPTIONS BUTTON AS IN EL SHERIF

DATA -- POSSIBLE FACTORS - JUST A DUMP

FORCE STRUCTURE
    - OVERHEAD/STAFF-SOF-DETCO-ETC
        ( PPA/SCHEDULED CHANGES)
        ( MOD/SCHEDULED UPGRADES)
        ( CREW COMPOSITION BY MOD)

MANNING LEVEL - BODIES VS AUTHORIZATIONS
    - RANK
    - AFSC
    - SCHEDULING ACQUISITIONS
        -- WHO'S LEAVING
            (CODE 55, TOS, AVG TOUR LENGTH, LOSS OR
            "PCA")
        -- NEW REQUIREMENTS
            (NEW PFT, COLLATERAL ACCESSION, RECAPTURE)
            (NEW REQUIREMENTS FROM FORCE STRUCTURE /
            BUILD-UP ISSUES)
    - PROFILES (PROJECTIONS/CONSEQUENCES)
        -- TABLES AND LINE

EXPERIENCE LEVELS - FULL UP CREWS
    - RANK
    - AFSC
    - LOSSES
    - MODELS - RECOMMENDATIONS OR RESPONSE
    - MODEL   (ALL ELEMENTS DATABASE INPUTS TO MODEL/
              ALSO POSSIBLE PARAMETERS)
    - TRAINING
    - EDUCATION
    - YEARS AWACS
    - # MISSIONS
    - # HOURS FLOWN
    - # INTERCEPTS
    - YEARS COLLATERAL EXPERIENCE

```
                    - ERROR HISTORIES
                        -- TAPE
                        -- LOGS
                        -- MAINT INPUT (E.G., CND)
                  - PROFILES(PROJECTIONS)/CONSEQUENCES
                        -- TABLES AND LINE
         SYSTEM CAPABILITIES/PERSONNEL IMPACT
                  - MODEL
                        (EFFECTIVE INTERCEPTS)      (REGRESSIONS)
                        (CONTINUOUS HARDWARE OPS)
                        (C3 BREAKDOWNS)
         - PROFILES(PROJECTIONS)/CONSEQUENCES
                  -- TABLES AND LINE REPRESENTATIONS


DATA --          DON'T FORGET DOS ETC AS INPUTS TO LOSS CALCULATIONS MAKE
                 SURE ALL DRIVERS FOR GAINS AND LOSSES ARE
                 CONSIDERED.
```

## Appendix D

### Data Requirements

This appendix lists the types of personnel data that can be useful for each of the major models needed to make the DSS function. The list is not comprehensive; only extensive "data snooping" at the user site can ensure all useful data is identified.

Data elements suggested for examination are listed with the location of the data. The 28 AD database mentioned is not currently in place, although it has been fully developed. Until such time as this database is fielded, the needed data can be found in the squadron ORCs.

As a general point, where data elements pertaining to time are concerned, the databases will often contain originating dates rather than cumulative time. Arriving at the necessary data will require subtracting the originating date from the current date.

## DATA BEARING ON MANNING LEVEL

|  | | SOURCE | |
| --- | --- | --- | --- |
|  | A-FORMS | CBPO | 28AD DB |
| **FORCE STRUCTURE CHANGES** | | | |
| 1. E-3 MODIFICATIONS | CURRENTLY, NOTE OF THIS | | |
| 2. ORGANIZATIONAL CHANGES | INFORMATION IS AUTOMATED. IT | | |
| 3. PAA CHANGES | DOES EXIST AT THE DIVISION | | |
| 4. CREWS/PAA CHANGES | AT 28 AD/XO. | | |
| | | | |
| **LOSS FACTORS** | | | |
| 5. AVERAGE TIME IN AWACS | | X | X |
| 6. AVERAGE TIME AT TINKER | | X | X |
| 7. CODE 55 LENGTH | | | X |
| 8. RANK | | X | X |
| 9. PLANNED RETIREMENT DATES | | X | X |
| 10. PLANNED SEPARATIONS DATES | | X | X |
| 11. SCHEDULED PCS DATES | | X | X |
| 12. LOSS RATES | | | |
|     BY TIME IN SERVICE | MPC CURRENTLY | | X |
|     BY RANK | " " | | X |
|     BY CREW AFSC | " " | | X |
|     BY # OF FLYING HOURS | X | | X |
| 13. NUMBER OF REMOTES | | X | X |
| | | | |
| **TRAINING LIMITATIONS** | | | |
| 12. CAPACITY | 552 TTS | | |

## PERSONNEL DATA POSSIBLY BEARING ON EXPERIENCE

|  | | SOURCE | |
| --- | --- | --- | --- |
|  | A-FORMS | CBPO | 28AD DB |
| **FLYING HISTORY** | | | |
| 1. TOTAL YEARS | X | | |
| 2. E-3 YEARS | X | | |
| 3. TOTAL HOURS | X | | |
| 4. E-3 HOURS | X | | |
| | | | |
| **SERVICE AND ASSIGNMENT SPECIFICS** | | | |
| 5. YEARS AWACS | | | |
|     CONUS | | X | X |
|     NATO, PACAF, ICELAND | | X | X |
| 6. NUMBER SHORT TOURS | | X | X |
| 7. NUMBER LONG TOURS | | X | X |
| 8. YEARS CURRENT CREW POSITION | | X | X |
| 9. YEARS OTHER AWACS POSITIONS | | X | X |
| 10. MAX STAFF LEVEL | | X | X |

|  | Col 1 | Col 2 | Col 3 |
|---|---|---|---|
| SQ (1); WING (2); DIVISION (3); HQS (4) | | | |
| 11. YEARS IN STAFF POSITIONS | | X | X |
| 12. APPLICABLE NON-AWACS EXPERIENCE | | | |
|     YEARS GROUND TACCs (WD, SD, AST) | | X | X |
|     YEARS C3 (FOR MCC, SD) | | X | X |
|     ABCCC | X | X | X |
|     RIVIT JOINT | X | X | X |
|     COMPASS CALL | X | X | X |
|     ETC. | | | |
| 13. YEARS IN SECONDARY RELATED AFSC (RADAR, COMPUTERS) | X | X | X |
| 14. GRADE | | X | X |
| 15. TIME IN SERVICE | | X | X |
| 16. TIME IN GRADE | | X | X |
| | | | |
| MISSION HISTORY | | | |
| 17. # SORTIES | X | | X |
| 18. # MISSIONS | X | | X |
| 19. # EXERCISE MISSIONS | X | | X |
| 20. # TEST MISSIONS/EVAL MISSIONS | X | | X |
| 21. # SIMULATOR SESSIONS | X | | X |
| 22. # OF CONTROLS/INTERCEPTS (SD, WD, ASD, AST) | X | | X |
| | | | |
| TRAINING AND PERFORMANCE SPECIFICS | | | |
| 23. FINAL TRAINING EVALUATION | | X | X |
| 24. ATTENDANCE OF SPECIAL SCHOOLS | | | |
|     FWS, TACATC (WD, SD, AST) | | X | X |
|     TYPE 2 TRAINING (CDMT, CT, CSO, ART) | | X | X |
| 25. STANEVAL RATINGS | | X | X |
| 26. YEARS SPECIAL POSITION (AAST) | | | X |
| 27. APR/OER | | X | |

# APPENDIX E

## Model Requirements

A description of the requirements for the three major models are included in this appendix. The descriptions for the manning level models and the capabilities models are very general. The modeling methodology for the kernel is discussed more fully.

## Manning Level Models

The manning level models drive the scheduling displays, and show the projected manning status of the crew positions. They must 1) project losses from the crew position, and 2) roll the projected acquisitions described by the manager during his "what-if" sessions back into the crew position to arrive at a manning level projection across a five year PFT planning period.

There are multiple available strategies available for projecting losses (and this is obviously the hard part of the model). For example, loss rates developed from historical data can be used. This can come from AWACS data, or, if that data is not currently available, MPC data may be available by general AFSC (to be used until AWACS specific historical data is collected). Another possibility is to use average time in AWACS estimate identify individuals who are likely to leave. The second method is probably more complex to implement, but should give truer results since it is know that loss rates are not constant across the years.

However losses are projected, care must be taken to make individual projections for distinctly different groups, and then aggregate these losses for an annual loss picture. As an example, first time AWACers accrue a service commitment (in the form of a code 55) that locks them into the AWACS system for some period of time. People returning to AWACS from other assignments do not have this commitment. Therefore, there may be a significant difference in the average time in AWACS for these two groups before they become lost to the AWACS manning pool.

Care must also be taken to project losses by personnel groupings

that are distinctly different in experience, so that the experience level models can make experience level projections. For example, if a major factor in experience level is rank, projected losses could be broken out by rank. Identifying losses by experience categories will allow the experience models to assess losses in experience do to departures from AWACS.

## Experience Level Models

The experience level models need to accomplish three distinct functions. First, they need to assess experience for each of the individuals in a crew position. This portion forms the kernel of the DSS presented here, and is discussed more extensively below.

The second function the model must perform is to manage changes in factor levels while projections are being made. (How these changes are managed is a key area of system assumptions that must be documented). As an example, if flying hours are significant in assessing experience, a distribution scheme for allocating flying hours beyond bare qualifications necessities is required. Obviously, the easy approach is to average the total flying hours available over the entire crew force. The question is, is this what actually happens, and if not, how different are the experience profiles developed using averages from those using a more difficult allocation scheme (over a five year period, this may be a moot point).

Finally, the model must make projections for experience levels across a five year period, using the factors discussed in the above two paragraphs, and the information of losses by category that the manning level model must provide.

With this general overview of the experience level model requirements, the rest of the discussion relative to experience modeling presented here pertains to the experience scoring method developed for the kernel DSS.

**Experience Scoring.** As discussed in chapters two and four, the approach adopted in the kernel DSS for developing experience scores was to use multiple regression with a binary response. Fundamentally, the approach used is to look at personnel data for factors that describe the difference between an identified set of suspected experts and the rest of the crew force, and to develop a probability measure that any given individual is a member of the expert group. It must be kept in mind here that there is no intent to ascribe cause and effect in this model. Using the model to allocate more flying hours (if flying hours are a factor in describing experience) to individuals with low experience scores may not be proper. The model may indicate that flying hours are useful for describing who experts are; it does not say that flying hours cause expertise.

As in all regression, the factors to be used in this particular formulation of a multiple regression are those that test significant in predicting the responses. However, Deming suggests that traditional statistics are in many ways poorly suited to describing non-static systems (i.e., systems that are not in a steady state). For non-static systems, he suggests that confidence intervals should not be an over riding consideration. Rather, emphasis should be placed on detecting gross patterns. For this DSS, with a goal of changing the system it examines, the system is known to be non-static. Therefore, significance

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levels for determining factors impacting experience should be relaxed. The goal here is not an exact answer, but rather a better answer.

552 AWACW/DO supplied a partial database on MCCs (with only a few personnel factors that could possibly bear on experience). Most of the factors available in the database were related to time in some manner; many of the factors discussed in the data section that should help to build a good scoring model were not available.

Using this data, a preliminary examination was conducted to test the usefulness of the scoring approach. As discussed in chapter 4, there are some problems with the technique used here that require remedial measures. One of the problems is that variance is non-uniform. This was addressed by using a weighted regression.

An unweighted regression was first conducted; the resulting predicted response was used to develop the appropriate weights

$$w_i = 1 / [\ Y_i(1-Y_i)\ ]$$

for the weighted regression, where $w_i$ is the weight for the $i^{th}$ observation and $Y_i$ is the predicted response for the same observation.

Corrections for responses out of the allowed range were not necessary for the data tested. If out of range responses had been observed, appropriate transformations are available to convert the formulation to a probit or logit regression. If this were not desired, other remedies could be available, depending upon the factors, and their real world implications for experience. As discussed previously, capping the maximum and minimum values certain variables can assume may make sense.

Results for the regression of the MCC data are shown below. For

the examination conducted, a p value of .4 was accepted as significant. While the weighted regression only accounts for 30% of the variance observed, this approach was still viewed as feasible (it is actually surprising to the author that 30% of the variance could be explained with the data at hand. This may bode well for the confidences that can be applied with better data).

## FACTOR LABELS

| | | |
|---|---|---|
| D = YEARS PRIOR SERVICE | DD = $D^2$ | DI = DxI interaction |
| E = TIME IN SERVICE | EE = $E^2$ | EI = ExI interaction |
| F = TIME IN GRADE | FF = $F^2$ | IH = HxI interaction |
| H = YEARS ON SHORT TOURS | | |
| I = YEARS ON LONG TOURS | | |

This is the regression that was conducted to establish weights. Factor I was retained (with a p value of .61) because of the interaction that were significant. $R^2$ is .21, and the model is significant at .15.

**Table 2** - Unweighted Regression

| PREDICTOR VARIABLES | COEFFICIENT | STD ERROR | STUDENT'S T | P |
|---|---|---|---|---|
| CONSTANT | -4.6440 | 1.5634 | -2.97 | 0.0042 |
| E | 6.1335E-01 | 1.9060E-01 | 3.22 | 0.0020 |
| F | -2.4483E-01 | 1.2412E-01 | -1.97 | 0.0528 |
| I | 6.8528E-02 | 1.3411E-01 | 0.51 | 0.6111 |
| DD | -2.7636E-02 | 1.0818E-02 | -2.55 | 0.0130 |
| EE | -1.3576E-02 | 4.6283E-03 | -2.93 | 0.0046 |
| FF | 1.6030E-02 | 9.5699E-03 | 1.68 | 0.0987 |
| DE | 1.8232E-02 | 1.3590E-02 | 1.34 | 0.1844 |
| DI | 2.2211E-02 | 1.2307E-02 | 1.80 | 0.0757 |
| D | -2.9569E-01 | 2.5881E-01 | -1.14 | 0.2574 |
| EI | -1.7528E-02 | 1.0546E-02 | -1.66 | 0.1013 |
| H | -3.7225E-01 | 2.1815E-01 | -1.71 | 0.0927 |
| HI | 1.3263E-01 | 6.3068E-02 | 2.10 | 0.0393 |
| | | | | |
| OVERALL F | 1.488 | P VALUE | 0.1514 | |
| R SQUARED | 0.2155 | | | |

As can be seen here, there is not a large separation in the
|experience scores of the two populations.   The lower grouping is for
the unknown portion of the crew, while the upper grouping is for the
instructors and StanEval personnel.   While the upper group has more
occurrences (as a percent of the upper group) at the high end of the X
axis, the range extend all the way to 0 (approximately).

```
S1
    3.0 +
        :
        :      ++
        :        ++
        :        2++  4+2   +
    1.0 +              2  +  +
        :                    4  2
        :                        +2+
        : +2445
        :     ++43 ++
   -1.0 +        254++
        :          +3+ +
        :          +    +
        :
        :
   -3.0 +
        --+----------+----------+----------+----------+--
        0.0        0.3        0.6        0.9        1.2
        P1    78 CASES PLOTTED
```
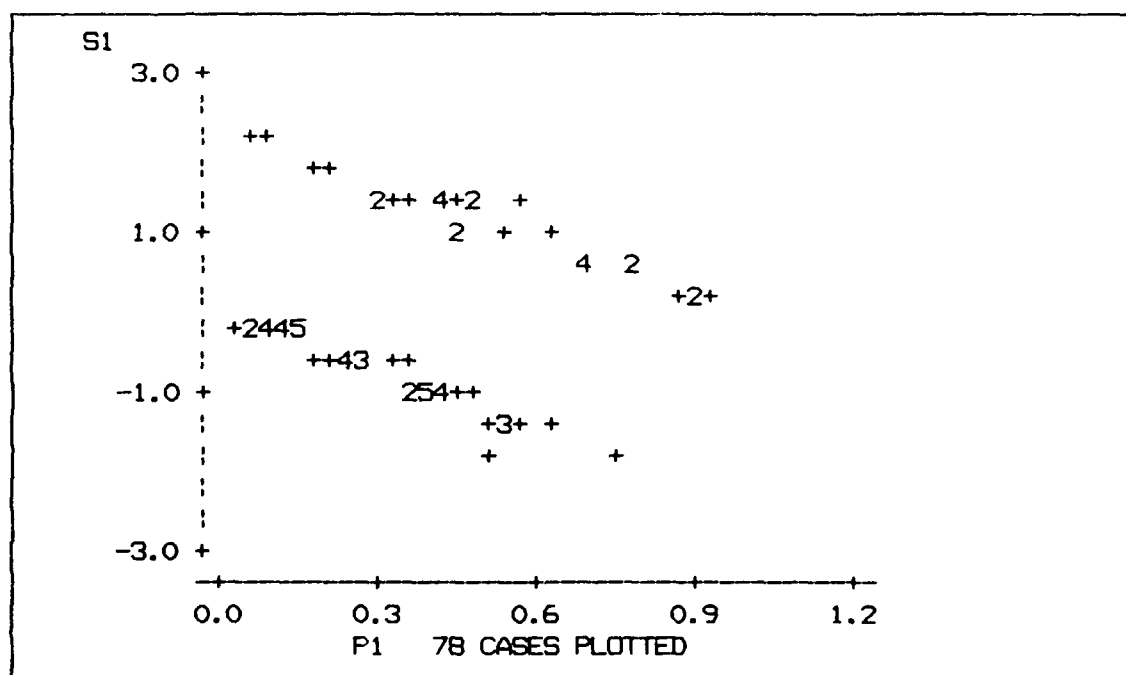
Figure 27 - Unweighted Regression Predictions

The second regression, using the weights developed in the first,
has an elevated $R^2$ (= .30) and a p value of .013.
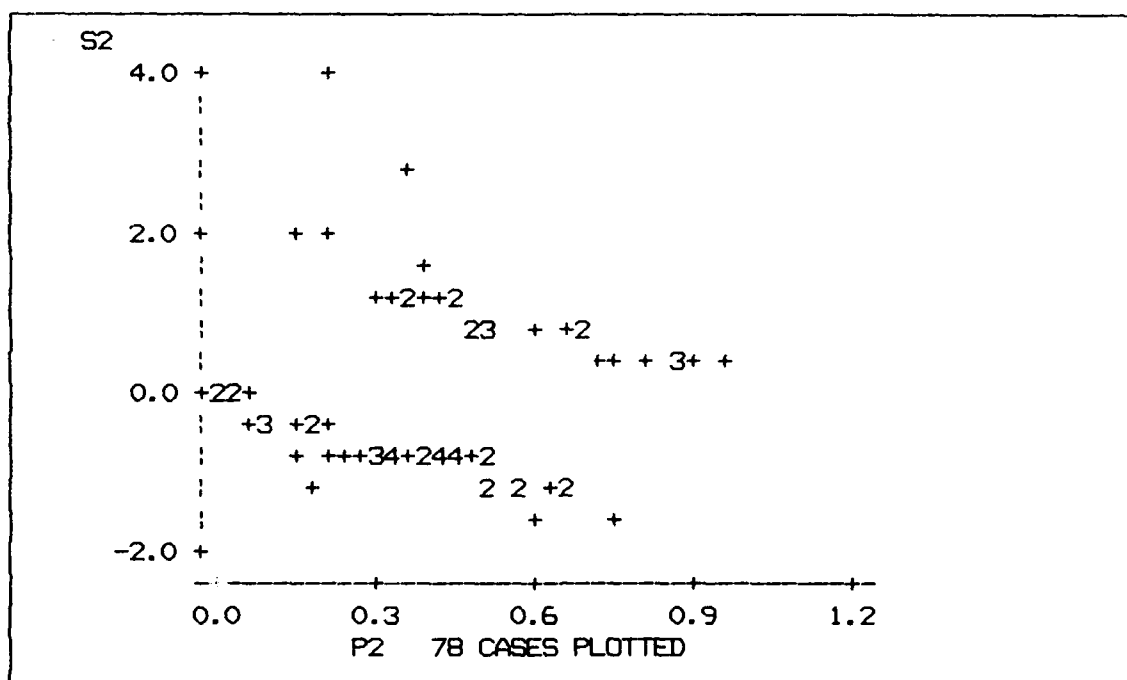
**Table 3 - Weighted Regression**

| PREDICTOR VARIABLES | COEFFICIENT | STD ERROR | STUDENT'S T | P |
|---|---|---|---|---|
| CONSTANT | -5.2769 | 1.3196 | -4.00 | 0.0002 |
| E | 6.7984E-01 | 1.6138E-01 | 4.21 | 0.0001 |
| F | -2.2977E-01 | 1.0795E-01 | -2.13 | 0.0371 |
| I | 1.1782E-01 | 1.1150E-01 | 1.06 | 0.2946 |
| DD | -2.4499E-02 | 1.0397E-02 | -2.36 | 0.0215 |
| EE | -1.5422E-02 | 3.9321E-03 | -3.92 | 0.0002 |
| FF | 1.5526E-02 | 8.8081E-03 | 1.76 | 0.0827 |
| DE | 2.4878E-02 | 1.3348E-02 | 1.86 | 0.0669 |
| DI | 1.2531E-02 | 1.1232E-02 | 1.12 | 0.2687 |
| D | -4.1322E-01 | 2.5779E-01 | -1.60 | 0.1138 |
| EI | -1.8017E-02 | 8.6067E-03 | -2.09 | 0.0402 |
| H | -3.7255E-01 | 2.1781E-01 | -1.71 | 0.0920 |
| HI | 1.1347E-01 | 5.4351E-02 | 2.09 | 0.0407 |

OVERALL F    2.380     P VALUE    0.0130

R SQUARED    0.3053

As can be seen in Figure 28, the result of weighting the regression was to better separated the two groups. The center of mass of the upper group has shifted higher on the X axis, while that of the lower group has moved down the axis.

## Capabilities Models

The capabilities model falls into the realm of MCDM, since it deals with balancing multiple objectives. This model should only address capabilities as impacted by personnel issues.

AWACS capabilities as a function of personnel is driven by multiple personnel issues, such as: 1) are there enough people to man a crew position; 2) are there enough experienced people in a crew position (average issues); 3) are there enough experts to handle exceptional cases and to pass on knowledge (distribution issues); 4) are there particular crew positions that are critical in impacting capabilities,

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```
S2
  4.0 +         +
      !
      !
      !              +
      !
  2.0 +      + +
      !              +
      !          ++2++2
      !             23  + +2
      !                  ++ + 3+ +
  0.0 +22+
      !  +3 +2+
      !     + +++34+244+2
      !       +        2 2 +2
      !                  +    +
 -2.0 +
      --!-----------+-----------+-----------+-----------+--
         0.0        0.3        0.6        0.9        1.2
         P2    78 CASES PLOTTED
```

Figure 2B - Weighted Regression Predictions

and 5) if so, do they need special attention to fix their deficiencies relative to the rest of the crew positions (allocation of scarce resources).

The objective of this model is not to provide an absolute answer on capability. Rather, the goal is to specify some measure that allows trends to be assessed. As such, the scale for "CAPABILITY" is not critical, but is sure to be a management stumbling block if some reference is not provided.

Approaches for providing reference include:

1) defining the 100 level to be 100% manning;

2) with a specified experience distribution (use the same distribution against which experience profiles are measured by acquisition managers), and;

3) with a "table" of trade offs between changes in these values

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clearly stated. Eliciting these trade offs (utilities and weights) is critical, and may well be the most difficult portion in developing this model. Every one of the assumptions made in estimating trade offs between these factors must be available to the decision makers that use the model.

The discussion above presents general guidelines for model development. Developing them will be a difficult and time consuming task.

# APPENDIX F

## MCDM Examination

This appendix discusses the examination made of MCDM techniques for the purpose of assessing experience levels in the different crew positions. While these methods were not adopted, they are applicable to other portions of the overall DSS. For example, MADA methods will probably be necessary if a reference (desired) experience profile is to be developed. Also, MCD techniques (not discussed in this appendix, since the area of concern was of a descriptive rather than prescriptive nature) will surely be necessary for developing the capabilities assessment models.

# Table of Contents

## Larger System Issues

The overall problem addressed in this research is the development of an effective decision aide to support AWACS air crew managers in determining personnel acquisition needs. (The manager's goal is to maintain AWACS with an crew force that can effectively execute the AWACS mission).

The acquisition requirements of AWACS are driven by two issues: 1) the number of people required to man a crew position, and; 2) the experience these people must possess for an AWACS mission to be effective. The first issue is concerned with personnel flow through the crew system. Managers attempt to keep crew positions fully manned. Quantitative shortages due to mis-timing of acquisitions (to fill manning vacancies) need to be minimized. The second issue is concerned with the distribution of experience in the crew force. All members of a crew position need not be expert, but some minimum set must be. There is also some limit to the number of novices the position can tolerate before the AWACS mission becomes ineffective due to inexperience in the crew position.

The overall measure of a successful manning acquisition program is how capable AWACS is of performing its mission (limited to effects based on personnel considerations). The AWACS capabilities issue involves some balance among the above mentioned factors (absolute numbers and experience). If the air crew managers are to be successful in managing acquisition, they must be able to balance experience and number issues to arrive at the best acquisition strategy.

In the overall problem, "optimizing" AWACS capabilities is a Multi-

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Criteria Optimization (MCO) problem, possibly addressed best as a compromise program. There are two criteria for each crew position in this problem. These criteria are:

1) The absolute manning level. The "ideal" and "goal" values for this criterion are the same. It is the manning authorization level for the crew position, as specified by higher headquarters.

2) The distribution of the experience in the crew position. The mean experience level of the personnel in the crew position is a possible measure of composite experience in the crew force. It can provide a basic measure of the ability of the current crew force to accomplish the AWACS mission effectively. The "goal" for the mean experience level will need to be extracted from the AWACS managers, and can be referenced against a constructed experience scale ranging from 0 to 1, where a .9 or greater is the "experience score" of the "ideal expert". (The distribution of experience is also critical, particularly with respect to a heavy representation in the crew force of novices, or a light representation of "expert" experts. However, all distribution issues will not be considered initially. Refinements of the models in the DSS will be necessary to account for more than central tendency. Some other moment will undoubtedly need to be considered to ensure unacceptable experience distributions in the crew force do not occur. The introduction of a "distribution" criteria in no way changes the basic approach needed; it only causes the dimensionality of the MCO problem to increase).

For managers to structure personnel acquisitions in a manner that "optimally" balances (under some MCO methodology) the two criteria just

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discussed, models are required that show the impact of a manning

acquisition decision on each of the criteria. A first step is

identifying the factors that bear on each of the criteria, i.e.,

identifying the attributes in the alternative space of each.

## The Kernel Problem

The kernel of the overall problem (discussed above) concerns the

"experience" issue. For most of the crew positions, there are no good

measures of the crew member's competence in his job performance. The

goal in the kernel development is to find and combine some set of

factors in an "experience score" that will provide a surrogate measure

of the individual crew member's effectiveness at his job. (The

individuals to be "scored" are the AWACS air crew members within each

crew position. Ratings are only relevant within the crew position, not

between positions. The score of interest is a rough estimate of each

individual's ability to competently handle all of the myriad of

contingencies that face crew members in his position in an AWACS

mission). To establish "experience scores", three tasks must be

accomplished. These tasks are to:

1) establish a set of factors that are reasonable indicators of

performance. Examples of possible candidate factors are: 1) rank, 2)

years of service, 3) Standardization Evaluation (StanEval) ratings, 4)

number of flying hours, 5) number of missions flown, 6) number of

exercise missions flown, etc.;

2) determine appropriate weights among the factors (if the experts

feel all are not of the same weight), and;

3) determine utility functions for each factor that describe the

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relationship between the states of the factor.

The "experience score" that is generated for each crew member will become part of his database attributes, so that the experience level of the crew position as a whole can be judged by simple graphic representations of the database contents. After a valid scoring method is arrived at, the experience profile of the crew force can be presented to the manager to enhance his acquisition recommendations. He will be able to identify what impact policies controlling acquisitions and losses have on the experience profile of the AWACS crew position. He will be able to assess issues such as:

1) whether he needs to take special actions to recapture experience (by identifying past AWACS members with the requisite experience who are at large in the AF manning pool, and whom MPC can reassign to AWACS to correct an imbalance), or whether he can "grow" that experience;

2) whether he can live with a manning acquisition that is composed entirely of novices, or;

3) whether he must get MPC and TAC to give him some mix of personnel that balances novice and experienced "acquisitions".

## An Assessment of a Multi-Criteria Decision Analysis (MADA) Approach to the Kernel

MADA, in this context, is oriented to the determination of experience based on expert opinion. Here, the objectives are to elicit appropriate experience factors from "the experts" and to determine the weights and utilities the experts hold for the factors. In general, the possible factors are only indicators of experience; rigorous descriptors of experience are not available. With no rigorous measures of

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experience, it is critical that a good set of indicators be identified, and their relative importance assessed.

The experts to be consulted are managers of the personnel to be rated. [For the purposes of assessing MADA in this research, the "experts" consulted were two Weapons Directors (WD) and two former AWACS analysts who were available locally. The crew position considered was the WD position]. Initially, the set of possible factors must be limited to those for which data is collected as an attribute of each individual. (The specification of a factor from the set of all conceivable factors is not useful at this point in time. If an expert feels that some attribute is valuable in determining experience, and data is not currently collected for the desired attribute, the identification can be used to instigate data collection. Better factors can be incorporated into the model at some later time).

The formulation of "experience score" needed in the kernel and the MADA methodology for arriving at the required weights and factors are presented in the following sections.

## Formulation for an "Experience Score"

The formulation of the "experience score" to be developed for each crew member is a simple additive model:

$$E = \sum_i [ (w^*)_i ] [ u_i(a_i) ] ,$$

where E is the "score", $w_i^*$ is the "standardized" weight for the $i^{th}$ factor, and $u_i(a)$ is the $i^{th}$ "utility value" that is a function of the $i_{th}$ attribute level in an individual crew member's attribute vector. In

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the above formulation, $w_i$ and $u_i$ are the weights and utilities that must be extracted from the experts. (Here, $w_i^*$ is $w_i$ "standardized" to give a maximum value of 1 to the score $E$ when $u_i(a_i) = 1$ for $i = 1,...,q$; where q is the number of factors in the model; in other words, the standardized weight is $w_i^* = [ w_i ] / [ \Sigma w_i ] )$. This model, while only being applied within a crew position, can be written in a general form that will score all crew positions. It does not have to be specialized by crew position. It can be written incorporating all factors identified for each crew position. All that is required to get consistent scores in a specific crew position is to maintain unique weighting and utility function vectors, and set the weight of any factor that is not applicable to 0, which removes the factor from the scoring model.

## Eliciting Factors Bearing on Experience

To elicit a set of possible factors from the experts, surveys were conducted. The surveys had two portions, one based on Semantic Scales and the other a Pair Comparison of factors [Chan].

**Part One of the Survey.** Part one of the survey contains a set of possible factors that may be of value and for which data is known to exist. The survey respondents completed two different evaluations of the factors.

The first evaluation of the factors was a semantic scaling survey to elicited perceived importance rankings for the factors. Rankings are on a five point scale (seven point scales are often used) where the extremes of the scale are described verbally. To complete the survey, the respondents were asked to establish rankings independently of all

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other factors.

The second evaluation of the factors was based on pair-wise comparisons of the factors. All factors are paired, and the respondents required to choose the preferred factor from the pair.

The two portions of this section of the survey have two purposes. These are: 1) to assess the importance of the various factors (both portions), and; 2) to check for consistency in the rankings. This is accomplished by comparing the two portions of the survey, and by assessing the transitivity of the factor rankings in the pair-wise comparison.

In the scheme of the overall survey, the first portion serves two further purposes. First, it may produce a good set of factors on its own, and second, it will get the expert thinking on the experience factor selection issue.

**Part Two of the Survey.** The second portion of the survey is basically unstructured. It consists of an open ended request for factors the experts deem important, such that the factors suggested are at least as valuable to the respondent as the most important factor identified in part one. This will mainly be used as a means of identifying possible new factors that have not been considered in the first section of the survey. However, under certain conditions, these factors may be included in the model to be developed.

**Selection of Factors.** The selection of factors will be based on two criteria. For factors evaluated in the first portion of the survey, any factor that is in the top two categories of the majority of the responses will be included. This selection criterion is used for the

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following reasons: 1) the response sample will be to small for statistical methods to be useful, and; 2) if a majority of the respondents agree that the factor is of above average importance, it should be considered until a larger response can be achieved.

For the factors identified in the second portion of the survey, any factor that appears on two or more surveys will be included. Here, the selection criterion is more liberal than in the first portion of the survey. This is done because if some factor appears on more than one survey, *solely from the respondents assessment of what is important and independent of survey prompts*, the factor is probably significant. (While an explicit pair-wise comparison is not conducted, guidance will be given that steers the respondent toward a mental pair-wise assessment of the relative strengths of the factors. This being so, a duplicate identification of the same factor will be considered sufficient justification for selecting the factor. Given more time and resources, this initial effort would be used as a pilot survey, and further surveying, incorporating the results of the pilot and with a larger sample, would be conducted. For the purposes of assessing MADA as an approach, this was not done).

## Eliciting Factor Weights and Utilities

Appropriate relative weights for the factors, and the utility function that describes the relationship of the states within each factor, can be determined through a series of reference lotteries. (This was discussed in the methodology portion of the main text, but is discussed here again).

In a "basic" reference gamble procedure, sequences of reference

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gambles are conducted where, prior to the gamble, payoffs for the reference gamble are established. Then, iteratively, probabilities $(p)$ for winning the gamble are assigned, and the certainty equivalent $(CE)$ for the gamble evaluated. Plotting $p$ verses $CE$ yields the utility curve for the factor being examined [Holloway : 422]. (Holloway also describes a variation on the basic reference gamble that fixes a sequence of certain values $(CV)$ and then determines the probability $p$ at which the decision maker is indifferent to the lottery. Plotting $p$ against $CV$ again yields the utility curve).

The reference gamble to be used is a 50-50 gamble. This is another modification of the basic reference gamble. (Holloway suggests that this is often a better gamble, since people often thing in terms of go-no go choices [428]). Here, $CE$s are first determined for $p = 0$, .5, and 1. For the rest of the procedure, $p$ is fixed at .5 and the $CE$s for each gamble elicited. The probability for the certain value can be determined from the gamble conducted. The 50-50 gamble was used to determine both the factor weights and the utility functions that describe the factors. This was done in an automated question and answer session. A sequence of structured questions were asked of the experts, and appropriate lotteries conducted. The results of the sessions were a set of weights and utility functions to be used in the additive "Experience Score" described first in the "Formulation" section of this appendix.

The software package "SmartEdge" (ver 3.0) was used to accomplish the structured question and answer sessions. Prior to the experts being asked to participate in the SmartEdge session, initial setup work was

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completed on a "Decision File" so that nothing was required of the experts but that they answer a the programs sequence of questions (i.e., all entries required up to the "DECISION MAKER DATA" were entered).

In a SmartEdge session, the expert being interviewed answered questions in the "DECISION MAKER DATA" segments of the software package. The results of the interview session defined the expert's utility function for each attribute listed. (A similar interview develops the appropriate weights for the factors).

## Survey

The survey included in at the end of this appendix (Tab A) is aimed at eliciting a set of factors that indicate experience in WDs. It was completed by four "experts". The results of the survey are presented next.

**Survey Results for Part I(a).** The results of the survey for Part (a) shown in Table D-1.

**Table 4 - Survey Results, Part I(a)**

|  | | IMPORTANCE | | | |
|---|---|---|---|---|---|
| FACTOR (RESPONDENT >> | 1 | 2 | 3 | 4 | (TOTAL) |
| A) StanEval ratings | 4 | 5 | 5 | 5 | (19) |
| B) E-3 flying hours | 2 | 3 | 4 | 4 | (13) |
| C) Years in position | 4 | 3 | 4 | 1 | (12) |
| D) Instructor qualified | 4 | 5 | 5 | 5 | (19) |
| E) # of E-3 missions | 3 | 3 | 4 | 3 | (13) |
| F) # of exercise missions | 4 | 4 | 4 | 4 | (16) |
| G) # of Simulator sessions | 2 | 2 | 3 | 3 | (10) |
| H) Training evaluations ... | 3 | 4 | 3 | 3 | (13) |
| I) ... ground controller ... | 4 | 4 | 2 | 3 | (13) |

Based on the selection criteria stated previously in this appendix,

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factors A, D and F appear to be a good set of indicators for WD experience. As stated previously, with a larger sample, a statistical evaluation of the results would be valuable. From the above table, it looks like factors E , H and I may also be possible experience indicators. A larger sample and a statistical measure would help determine if they are indeed useful indicators.

**Survey Results for Part I(b).** Evaluation of the results of Part I(b) resulted in a change in the factor selection criteria, and in the factors selected. Examination of the paired comparisons showed that three of the respondents surveyed considered the set of factors to be fully transitive. Further, the preference structure established by the comparisons were consistent with each respondents answers in Part I(a) of the survey [within the resolution of the scale of Part I(a)]. (The transitivity of the factors was established on a spreadsheet. One compound sort of the factors ranked the respondents preference for the factors. The sorted responses for one survey are included in Tab B).

The fourth respondent's survey results demonstrated intransitivities and also indicated inconsistencies with his responses in Part I(a) of the survey. This respondent was not available for further questioning (member was TDY) that might have revealed why the intransitivities existed and why there was not good correlation pattern between his Part I(a) and Part I(b) responses. His responses were therefore removed from consideration in the study.

**Reduced Response Set.** While three of the respondents were internally consistent in their rankings, their rankings in the pair-wise comparison did not agree fully with each other. Two agreed exactly in

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the ranking of the top four factors. The third included only one of these factors (A) in his first four choices. The factor preferences established by the pair-wise comparison are:

1)    A > I > D > C > F > E > H > B > G
2)    D > A > F > E > C > I > B > H > G
3)    D > A > F > E > H > I > C > B > G

**Survey Clarification.** Further questioning of the respondents showed that there was a fundamentally different perception about the scenario under which they were operating in Part I(b) of the survey. The two respondents who were most in agreement operated from the assumption that there was no guarantee that any of the crew members they were to choose from would have ground control experience, and would therefore not attempt to base a decision on this factor. Further, they both indicated that this assumption was based on their knowledge that there are not many people in the AWACS community with ground control experience. (When asked if this wasn't also true for basing a decision on instructor qualification, they indicated that they were indeed operating from the same assumption. However, the indicated that 1) there are many more people in AWACS who have been instructors at some time, so they felt there was a much better chance that pool of crew members to be drawn from would include members with instructor backgrounds, and 2) that instructor qualification was such a good discriminator of expertise, that they were willing to "gamble" on finding someone with this background).

The respondent who was not in agreement with the other two, on considering these issues, indicated that factor I would move down in his rankings if it were unknown if any crew members in the pool to be drawn

from had ever been ground controllers. He had based his rankings on the assumption that the pool to be drawn from contained members in every factor category.

**Survey Results of Part II.** Part II of the survey produced two more possible factors. One factor appeared on three surveys and one appeared on two. These new factors were:

1) Has the WD ever been a StanEval flight performance evaluator. If so, this is a highly reliable indicator of experience, based on comments included on the surveys. This factor appeared on three surveys.

2) Has the member attended the Fighter Weapons School (FWS) or the Tactical Air Traffic Control (TACATC) training courses. If so, this is also a reliable indicator of experience. This are very limited courses in advanced control tactics that only a chosen few get into. Special schools appeared on two surveys.

**Independence Issues.** During the survey clarification discussed above, another issue that came out had to do with the independence of the factors. Consideration of the factor set led to the following conclusions:

1) number of missions flown, number of exercise missions flown, and number of simulator sessions could be considered to be largely independent, but all three were related to number of years in the crew position;

2) factors like instructor qualification, special school attendance and the respondent suggested standardization evaluator qualification factor were not independent of most of the other factors,

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and;

3) any crew members who were instructor or standardization qualified or who had attended any of the special schools could be considered experts because of the screening they had been through before they were selected for these positions. Members selected for these functions were highly qualified before their selection; the experience gained by filling the positions or going to schools only reinforced their expertise.

Fundamentally, member's who were ever instructors or standardization evaluators, or who had been to special schools should be considered "experts", and removed to a separate "pot". *These factors can be used in a Lexicographic screening of the WD population. They are sure indicators that a member is "experienced". The Instructor qualification and Standardization Evaluator qualification factors can be rolled into one factor that guarantees preference for WDs with either qualification, and the Special Schools factor can be used as a second factor in the lexicographic ordering of "experts" with attendance of more special schools preferred.* (Further distinction among experts may be possible. The survey participants felt the only factors among those listed or elicited that might distinguish experience among the experts would be B, E, and possibly F).

**Altered Factor Selection.** Given the above discussion, the criteria for factor selection was altered to pick the factors that met the original criteria and that had minimum score of 3. When there were four respondents, and all three of the four agreed that a factor was of above average importance, the presence of an "outlier" could be tolerated.

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With only three respondents left in the sample, the criteria was altered so that one rating of below average for a factor raises sufficient question about its worth to remove it from consideration. Further, having identified that factor C was not independent of some of the other measures, it was removed from the set of factors to be considered. Finally, the rating question was divided into two areas: 1) separate out the guaranteed "experts" using factor D (and experience as a Standardization Evaluator and attendance of one or more of the premier controller schools, as discussed in the next section).

The results of Part I(a) of the survey with the inconsistent respondees data removed are shown in Table D-2, below. The factors that meet the selection criteria are indicated.

Table 3 - Survey Results, Part I(a), Modified

| | | IMPORTANCE | | | | INCLUDED | |
|---|---|---|---|---|---|---|---|
| FACTOR | (RESPONDENT >>1 | | 2 | 3 | (TOTAL) | NOW | PREVIOUSLY |
| A) | StanEval | 4 | 5 | 5 | (14) | * | * |
| B) | Fly Hours | 2 | 3 | 4 | ( 9) | | |
| C) | Years Flm | 4 | 3 | 4 | (11) | | |
| D) | Inst Qual | 4 | 5 | 5 | (14) | | * |
| E) | Missions | 3 | 3 | 4 | (10) | | |
| F) | Exercise | 4 | 4 | 4 | (12) | * | * |
| G) | Sim | 2 | 2 | 3 | ( 7) | | |
| H) | TrainEval | 3 | 4 | 3 | (10) | | |
| I) | GrndCont | 4 | 4 | 2 | (10) | | |

The pair-wise comparison results with factors C, D and I removed (C for non-independence, D because it will be used as part of a Lexicographic screening of the WD population, and I because of the difference in respondent treatment of the factor) is presented below. Transitivity of the results for each respondent is maintained since removal of factors causes no changes, and no new factors were added.

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```
1)     A > F > E > H > B > G
2)     A > F > E > B > H > G
3)     A > F > E > H > B > G
```

Using the above information, SmartEdge was configured to elicit the weights and utilities of the remaining factors.  The SmartEdge sessions are discussed next.

## SmartEdge Session

Assessment of utilities and weights for use in a value function formulation was accomplished in a SmartEdge session with the two remaining factors, i.e.,  A) StanEval ratings, and  F)  # of exercise missions.  (This assessment is done for the WD population left after the population has been screened for "experts" as discussed above).

Independence issues are treated at the Utility Independence level by SmartEdge.  Preferential Independence is not explicitly checked, since given Utility Independence "it is difficult to construct a realistic example where pair-wise utility independence would be violated" [SmartEdge Documentation : B-11].  Given that the set of factors has been reduced to two, this is a moot point.  (With more than two factors, Preferential Independence may have to be verified prior to using a package like SmartEdge).  Utility Independence and Preferential Independence are the same in this case.

The SmartEdge session was conducted by defining a set of alternatives in the CASE DEFINITION area of the program.  The alternatives in this case are "WDs" to be ranked by preference. ("Representative WDs" were built at 10 different levels of experience. Each was assigned representative attribute values that might be expected

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at these levels of experience). This constituted the necessary set-up work to allow the session to enter the weight and utility determination phase.

Establishing utilities for each factor and the weights between factors entailed the surrogate decision maker (only one of the WDs had time for the SmartEdge session) passing through two sequences of reference lotteries. Utilities were arrived at by establishing the decision maker's (DM) trade-offs within a specific factor, and the weights were developed by assessing preferences expressed by gambles between specified trade-offs between the factors.

Having produced the utilities and weights, SmartEdge was asked to rank the representative WDs that were defined as the alternative space of the problem. All were ranked in the order expected, and the assigned utility scores were proportional to the expected difference in experience levels among the alternatives. Data for real WDs, obtained from Tinker AFB, OK, was then entered into the alternative space, and the program was executed again. The real WDs were also ranked appropriately (Tab C).

## Conclusions

The methodology examined here gave results that made sense. However, there are probably many better discriminators of experience for the "non-experts" that should be examined. As these factors are included, the dimensionality of the problem increases rapidly, making solutions more difficult. Further, when multiple experts differ on utilities and weights, MADA has some problems. Various concordance measures are available for determining whether differences observed

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between the elicited values are significant. Unfortunately, when the concordance measures indicate significant disagreement, MADA currently has no generally accepted means for resolving the dispute.

Possibly a more significant problem in this instance is the level of expert involvement required to implement this type of strategy, and the difficulty the experts have in understanding the utility and weighting elicitation process. For this simple test, weights and utilities were only developed for two factors. This process took over six hours to accomplish, using a reasonably friendly software package. The major problem encountered was that, even using a 50-50 gamble (which Holloway indicated is generally the most easily understood), the decision maker being queried could not build a utility curve that matched his estimations, *even when he had a clear perception of what the curve should look like*. People in general do not deal with probabilities well, and this experience indicates they have particular problems estimating the relative probabilities for two different bounded ranges (not including either extreme) in the interior of the space they are considering.

The time issue is critical for the DSS. The people who will be queried in this process at Tinker AFB are 1) non-technical, and 2) flyers who have a erratic, and very full, schedules. Attempting to corral the personnel support from the experts to repeat the MADA approach for 12 crew position with multiple factors, multiple times as the system evolves, will probably kill the DSS development outright. As such, this approach should only be used as a last resort, when other less time intensive (flyer's time) methods have been found insufficient.

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Having said this, it must also be said that, while these techniques are difficult to apply to the current problem, they do offer an alterative means of looking at the personnel data that applies to the problem. The process of dealing with experts is illuminating, and results in a much better understanding of a problem than results from a bare examination of personnel data using statistical techniques. As such, there is some value in an analyst "squandering" (from the expert's perspective) a little expert time to gain the insights can be gleaned using these techniques.

Tab A — The Survey

To get a measure of the "experience level" of the WD crew force, a "quantifying" scheme is being be developed that calculates an "experience score" for every WD in AWACS. The quantifying scheme will depend on factors that you indicate provide valuable indications of individual experience. Please give your undivided consideration to each answer you provide. Your contributions will be invaluable in managing new personnel acquisitions.

Assume you must pick the WD's for the crew going on a critical mission. Further, assume you have no personal knowledge of the WDs you have available to form the crew. All you have is information from various databases that contain career information on each candidate.

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PART I(a).

The following questions show a scale relating to the importance of various data elements. These data elements are available, and may be helpful to you in forming the best crew possible from the available personnel. With the situation describe above, select the scale value that best describes the value you would place on the having access to the indicated data to help you assess the candidates experience. The scale values correspond to the following descriptions:

Data in this area is _____ in selecting the best men for this job.

        1 — not useful
        2 — somewhat useful
        3 — useful
        4 — very useful
        5 — exceptionally valuable

Note: Make your assessment based only on the data element being considered. Do not make your assessment to the other data elements discussed in the survey.


## DATA ELEMENT

1) StanEval ratings on last three check rides

    Not useful      1——— 2 ——— 3 ——— 4 ——— 5    very valuable

2) Total E-3 flying hours

    Not useful      1——— 2 ——— 3 ——— 4 ——— 5    very valuable

3) Years in position

    Not useful      1——— 2 ——— 3 ——— 4 ——— 5    very valuable

The scale values descriptions are repeated here for your convenience.
Data in this area is _____ in selecting the best men for this job.

        1 -- not useful
        2 -- somewhat useful
        3 -- useful
        4 -- very useful
        5 -- exceptionally valuable

Note:  Make your assessment based only on the data element being
considered.  Do not make your assessment to the other data elements
discussed in the survey.


4)   Instructor qualified at some time

     Not useful      1____ 2 ____ 3 ____ 4 ____ 5      very valuable

5)   Number of E-3 missions flown

     Not useful      1____ 2 ____ 3 ____ 4 ____ 5      very valuable

6)   Number of exercise missions flown

     Not useful      1____ 2 ____ 3 ____ 4 ____ 5      very valuable

7)   Number of Simulator sessions

     Not useful      1____ 2 ____ 3 ____ 4 ____ 5      very valuable

8)   Training evaluations for courses in the WD training sequence

     Not useful      1____ 2 ____ 3 ____ 4 ____ 5      very valuable

9)   Number of controls if from a ground controller background

     Not useful      1____ 2 ____ 3 ____ 4 ____ 5      very valuable

PART I(b).

In this portion of the survey, you are asked to compare the data elements in the previous section two at a time. Based on the pair-wise comparison stated in each of the following questions, please select the data element you most value in selecting the WDs for the crew you are forming. Indicate your choice by circling the appropriate choice in the center column. Try to answer all questions. Ties are not allowed.

If I could only have one piece of information, I would prefer to know each candidate WD's

## CIRCLE I or II

| | | |
|---|---|---|
| 1) Years in position | I or II | Instructor qualification status (all of career) |
| 2) Total E-3 flying hours | I or II | Training evaluations for all courses in the WD training sequence |
| 3) StanEval ratings on last three check rides | I or II | Instructor qualification status (all of career) |
| 4) Years in position | I or II | Number of controls if previously a ground controller |
| 5) Number of E-3 missions flown | I or II | Training evaluations for all courses in the WD training sequence |
| 6) StanEval ratings on last three check rides | I or II | Training evaluations for all courses in the WD training sequence |
| 7) Instructor qualification status (all of career) | I or II | Number of simulator sessions |
| 8) Total E-3 flying hours | I or II | Years in position |
| 9) StanEval ratings on last three check rides | I or II | Total E-3 flying hours |
| 10) Total E-3 flying hours | I or II | Number of exercise missions flown |
| 11) Training evaluations for all courses in the WD training sequence | I or II | Number of controls if previously a ground controller |

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If I could only have one piece of information, I would prefer to know each candidate WD's

<u>CIRCLE I or II</u>

12) Instructor qualification  I  or  II  Number of E-3 missions
    status (all of career)                flown

13) Number of exercise     I  or  II  Training evaluations for
    missions flown                      all courses in the WD
                                        training sequence

14) Total E-3 flying hours  I  or  II  Number of E-3 missions
                                        flown

15) StanEval ratings on    I  or  II  Number of exercise
    last three check rides              missions flown

16) Years in position      I  or  II  Number of simulator
                                        sessions

17) Number of simulator    I  or  II  Number of controls
    sessions                            if previously a ground
                                        controller

18) StanEval ratings on    I  or  II  Years in position
    last three check rides

19) Instructor qualification  I  or  II  Number of exercise
    status (all of career)                sessions flown

20) Number of simulator    I  or  II  Training evaluations for
    sessions                            all courses in the WD
                                        training sequence

21) Years in position      I  or  II  Number of E-3 missions
                                        flown

22) StanEval ratings on    I  or  II  Number of controls if
    last three check rides              previously a ground
                                        controller

23) Total E-3 flying hours  I  or  II  Instructor qualification
                                        status (all of career)

24) Number of exercise     I  or  II  Number of controls
    missions flown                      if previously a ground
                                        controller

If I could only have one piece of information, I would prefer to know each candidate WD's

## CIRCLE I or II

25) Number of E-3 missions flown     I or II     Number of simulator sessions

26) StanEval ratings on last three check rides     I or II     Number of E-3 missions flown

27) Years in position     I or II     Number of exercise missions

28) Total E-3 flying hours     I or II     Number of simulator sessions

29) StanEval ratings on last three check rides     I or II     Number of simulator sessions

30) Total E-3 flying hours     I or II     Number of controls if previously a ground controller

31) Instructor qualification status (all of career)     I or II     Training evaluations for all courses in the WD training sequence

32) Number of E-3 missions flown     I or II     Number of exercise missions flown

33) Years in position     I or II     Training evaluations for all courses in the WD sequence

34) Number of exercise missions flown     I or II     Number of simulator sessions

35) Number of E-3 missions flown     I or II     Number of controls if previously a ground controller

36) Instructor qualification status (all of career)     I or II     Number of controls if previously a ground controller

PART II.

Please take a few moments to indicate factors that would be
valuable indicators of a WDs experience. If you choose to list some
factors, please limit your suggestions to those that you think are at
least as good an indicator as the one you feel is the best in the set
you have been answering questions about.

1. _____

2. _____

3. _____

4. _____

5. _____

Tab B — Example Transitivity Examination

| QUESTION NUMBER | PAIR COMPARED | | RESPONDENT 1 | PREFERENCE BY GROUP |
|---|---|---|---|---|
| 9 | A | B | A | |
| 18 | A | C | A | |
| 3 | A | D | A | |
| 26 | A | E | A | A preferred over |
| 15 | A | F | A | all |
| 29 | A | G | A | |
| 6 | A | H | A | |
| 22 | A | I | A | |
| | | | | |
| 8 | B | C | C | |
| 23 | B | D | D | |
| 14 | B | E | E | |
| 10 | B | F | F | C,D,E,F,H,I > B > G |
| 28 | B | G | B | |
| 2 | B | H | H | |
| 30 | B | I | I | |
| | | | | |
| 1 | C | D | D | |
| 21 | C | E | C | |
| 27 | C | F | C | D,I > C > E,F,G,H |
| 16 | C | G | C | |
| 33 | C | H | C | |
| 4 | C | I | I | |
| | | | | |
| 12 | D | E | D | |
| 19 | D | F | D | |
| 7 | D | G | D | I > D > E,F,G,H |
| 31 | D | H | D | |
| 36 | D | I | I | |
| | | | | |
| 32 | E | F | F | |
| 25 | E | G | E | F,I > E > G,H |
| 5 | E | H | E | |
| 35 | E | I | I | |
| | | | | |
| 34 | F | G | F | |
| 13 | F | H | F | I > F > G,H |
| 24 | F | I | I | |
| | | | | |
| 20 | G | H | H | H,I > G |
| 17 | G | I | I | |
| | | | | |
| 11 | H | I | I | I > H |

The overall preference order expressed by respondent one was fully transitive, and is:   A > I > D > C > F > E > H > B > G

Tab C — SmartEdge Output

SmartEdge was exercised in four different modes to see how different the results were for the project problem. These run modes were:

1) Additive Model -- Probabilistic
2) Additive Model -- Deterministic
3) Multiplicative Model -- Probabilistic
4) Multiplicative Model -- Deterministic

All four applications of returned the same ranking. Further, the differences in the utility values differed by at most 2%.

In this case, there is no significant difference between the additive and multiplicative model results. Further, the results were insensitive to the uncertainty in attribute level set for the initial "representative WDs".

The edited summary reports for these runs follow. The editing consists of removing Section III which reports on differences among multiple decision makers (only one used) and the inclusion of only one set of appendices (Section IV) for the four runs, since the information for all runs remained the same.

SUMMARY REPORT CONTENTS
FOR ALL CASES


This report summarizes the results of PROBABILISTIC/ADDITIVE as follows:

I    Introduction and Case Specifications

A.   The Alternatives
B.   The Attributes
C.   The Decision Makers
D.   The Analysis Mode
E.   The Run Option
F.   The Decision Model

II   Individual Decision Maker Rankings

III  Decision Maker Rankings As a Group  (NOT INCLUDED -- ONLY 1 DECISION
     MAKER)

IV   Appendices (INCLUDED) AFTER THE ANALYSIS OF ALL FOUR RUNS)

A.   The Attribute State/Distribution Inputs
B.   The Preference Inputs for Each Decision Maker

SUMMARY REPORT
FOR CASE: PROBABILISTIC/ADDITIVE

# SECTION I
## INTRODUCTION AND CASE SPECIFICATIONS

This Section presents the specifications for the decision making case defined.

A. The Alternatives are:

Alterative 1 = 1
Alterative 2 = 2
Alterative 3 = 3
Alterative 4 = 4
Alterative 5 = 5
Alterative 6 = 6
Alterative 7 = 7
Alterative 8 = 8
Alterative 9 = 9
Alterative 10 = 10
Alterative 11 = BEENAROUND
Alterative 12 = SEENSOME1
Alterative 13 = SEENSOME2
Alterative 14 = OLDDOG

B. The Attributes are:

Attribute 1 = StanEval Ratings
Attribute 2 = #ExerciseMissions

C. The Decision Makers are:

Individual 1 = DM2

D. Mode of Analysis Selected is: Detailed Analysis Mode

E. Run Option for Uncertainty is: Probabilistic

F. Type of Decision Model is: Simple Linear (Additive) Model

# SECTION II
## INDIVIDUAL DECISION MAKER RANKINGS

This Section presents the results of a multi-attribute decision analysis for the Case PROBABILISTIC/ADDITIVE with rankings for each decision maker.

Rankings for Decision Maker:   DM2

| Alternative | Value | Rank |
|---|---|---|
| 1 | 0.0776 | 14 |
| +/- | 0.0327 | |
| 2 | 0.1261 | 13 |
| +/- | 0.0457 | |
| 3 | 0.1633 | 12 |
| +/- | 0.0596 | |
| 4 | 0.2521 | 9 |
| +/- | 0.0736 | |
| 5 | 0.3263 | 8 |
| +/- | 0.0767 | |
| 6 | 0.3388 | 7 |
| +/- | 0.0988 | |
| 7 | 0.4429 | 6 |
| +/- | 0.1227 | |
| 8 | 0.4607 | 5 |
| +/- | 0.1254 | |
| 9 | 0.6032 | 3 |
| +/- | 0.1399 | |
| 10 | 0.6768 | 2 |
| +/- | 0.1193 | |
| BEENAROUND | 0.5342 | 4 |
| +/- | 0.0005 | |
| SEENSOME1 | 0.2465 | 10 |
| +/- | 0.0002 | |
| SEENSOME2 | 0.1758 | 11 |
| +/- | 0.0001 | |
| OLDDOG | 0.9088 | 1 |
| +/- | 0.0004 | |

The rankings are in Agreement at a 95 percent significance level.

SUMMARY REPORT
FOR CASE: DETERMINISTIC/ADDITIVE

## SECTION I
## INTRODUCTION AND CASE SPECIFICATIONS

This Section presents the specifications for the decision making case defined.

A.   The Alternatives are:

| | |
|---|---|
| Alterative 1 = | 1 |
| Alterative 2 = | 2 |
| Alterative 3 = | 3 |
| Alterative 4 = | 4 |
| Alterative 5 = | 5 |
| Alterative 6 = | 6 |
| Alterative 7 = | 7 |
| Alterative 8 = | 8 |
| Alterative 9 = | 9 |
| Alterative 10 = | 10 |
| Alterative 11 = | BEENAROUND |
| Alterative 12 = | SEENSOME1 |
| Alterative 13 = | SEENSOME2 |
| Alterative 14 = | OLDDOG |

B.   The Attributes are:

Attribute 1 =    StanEval Ratings
Attribute 2 =    #ExerciseMissions

C.   The Decision Makers are:
Individual 1 =      DM2

D.   Mode of Analysis Selected is:   Detailed Analysis Mode

E.   Run Option for Uncertainty is: Deterministic

F.   Type of Decision Model is:    Simple Linear (Additive) Model

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## SECTION II
## INDIVIDUAL DECISION MAKER RANKINGS

This Section presents the results of a multi-attribute decision analysis
for the Case DETERMINISTIC/ADDITIVE with rankings for each decision
maker.

Rankings for Decision Maker:    DM2

| Alternative | Value | Rank |
|---|---|---|
| 1 | 0.0793 | 14 |
| 2 | 0.1221 | 13 |
| 3 | 0.1650 | 12 |
| 4 | 0.2521 | 9 |
| 5 | 0.3259 | 8 |
| 6 | 0.3532 | 7 |
| 7 | 0.4262 | 6 |
| 8 | 0.4550 | 5 |
| 9 | 0.6055 | 3 |
| 10 | 0.6616 | 2 |
| BEENAROUND | 0.5342 | 4 |
| SEENSOME1 | 0.2465 | 10 |
| SEENSOME2 | 0.1758 | 11 |
| OLDDOG | 0.9088 | 1 |

The rankings are in Agreement at a 95 percent significance level.

SUMMARY REPORT
FOR CASE: PROBABILISTIC/MULTIPLICATIVE

## SECTION I
## INTRODUCTION AND CASE SPECIFICATIONS

This Section presents the specifications for the decision making case defined.

A. The Alternatives are:

| | |
|---|---|
| Alterative 1 = | 1 |
| Alterative 2 = | 2 |
| Alterative 3 = | 3 |
| Alterative 4 = | 4 |
| Alterative 5 = | 5 |
| Alterative 6 = | 6 |
| Alterative 7 = | 7 |
| Alterative 8 = | 8 |
| Alterative 9 = | 9 |
| Alterative 10 = | 10 |
| Alterative 11 = | BEENAROUND |
| Alterative 12 = | SEENSOME1 |
| Alterative 13 = | SEENSOME2 |
| Alterative 14 = | OLDDOG |

B. The Attributes are:

Attribute 1 =    StanEval Ratings
Attribute 2 =    #ExerciseMissions

C. The Decision Makers are:

Individual 1 =       DM2

D. Mode of Analysis Selected is:   Detailed Analysis Mode

E. Run Option for Uncertainty is: Probabilistic

F. Type of Decision Model is: Detailed Non-Linear (Multiplicative) Model

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## SECTION II
## INDIVIDUAL DECISION MAKER RANKINGS

This Section presents the results of a multi-attribute decision analysis for the Case PROBABILISTIC/MULTIPLICATIVE with rankings for each decision maker.

Rankings for Decision Maker:    DM2

| Alternative | Value | Rank |
|---|---|---|
| 1 | 0.0739 | 14 |
| +/- | 0.0312 | |
| 2 | 0.1205 | 13 |
| +/- | 0.0437 | |
| 3 | 0.1565 | 12 |
| +/- | 0.0573 | |
| 4 | 0.2420 | 9 |
| +/- | 0.0708 | |
| 5 | 0.3146 | 8 |
| +/- | 0.0741 | |
| 6 | 0.3285 | 7 |
| +/- | 0.0964 | |
| 7 | 0.4308 | 6 |
| +/- | 0.1210 | |
| 8 | 0.4496 | 5 |
| +/- | 0.1235 | |
| 9 | 0.5941 | 3 |
| +/- | 0.1399 | |
| 10 | 0.6657 | 2 |
| +/- | 0.1191 | |
| BEENAROUND | 0.5263 | 4 |
| +/- | 0.0004 | |
| SEENSOME1 | 0.2404 | 10 |
| +/- | 0.0001 | |
| SEENSOME2 | 0.1689 | 11 |
| +/- | 0.0002 | |
| OLDDOG | 0.8800 | 1 |
| +/- | 0.0008 | |

The rankings are in Agreement at a 95 percent significance level.

SUMMARY REPORT
FOR CASE: DETERMINISTIC/MULTIPLICATIVE

# SECTION I
## INTRODUCTION AND CASE SPECIFICATIONS

This Section presents the specifications for the decision making case defined.

A.  The Alternatives are:

Alterative 1 =          1
Alterative 2 =          2
Alterative 3 =          3
Alterative 4 =          4
Alterative 5 =          5
Alterative 6 =          6
Alterative 7 =          7
Alterative 8 =          8
Alterative 9 =          9
Alterative 10 =         10
Alterative 11 =    BEENAROUND
Alterative 12 =     SEENSOME1
Alterative 13 =     SEENSOME2
Alterative 14 =       OLDDOG

B.  The Attributes are:
Attribute 1 =     StanEval Ratings
Attribute 2 =     #ExerciseMissions

C.  The Decision Makers are:
Individual 1 =        DM2

D.  Mode of Analysis Selected is:   Detailed Analysis Mode

E.  Run Option for Uncertainty is: Deterministic

F.  Type of Decision Model is: Detailed Non-Linear (Multiplicative) Model.

## SECTION II
## INDIVIDUAL DECISION MAKER RANKINGS

This Section presents the results of a multi-attribute decision analysis for the Case DETERMINISTIC/MULTIPLICATIVE with rankings for each decision maker.

Rankings for Decision Maker:    DM2

| Alternative | Value | Rank |
|---|---|---|
| 1 | 0.0756 | 14 |
| 2 | 0.1167 | 13 |
| 3 | 0.1580 | 12 |
| 4 | 0.2421 | 9 |
| 5 | 0.3143 | 8 |
| 6 | 0.3426 | 7 |
| 7 | 0.4139 | 6 |
| 8 | 0.4435 | 5 |
| 9 | 0.5963 | 3 |
| 10 | 0.6503 | 2 |
| BEENAROUND | 0.5263 | 4 |
| SEENSOME1 | 0.2404 | 10 |
| SEENSOME2 | 0.1689 | 11 |
| OLDDOG | 0.8800 | 1 |

The rankings are in Agreement at a 95 percent significance level.

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# SECTION IV
## DATA INPUTS

This Section presents the inputs for Case PROBABILISTIC/ADDITIVE used to compute the rankings.

A.   The Attribute State/Distribution Inputs:

Attribute States for Alternative : 1

Cumulative Distribution for StanEval

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 1.0000 | 0.00 | 2.0000 | 0.50 | 3.0000 | 1.00 |
| 2.0000 | 0.25 | 2.0000 | 0.75 | | |

Cumulative Distribution for #ExerciseMissions

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 0.0000 | 0.00 | 2.0000 | 0.50 | 3.0000 | 1.00 |
| 0.0000 | 0.25 | 3.0000 | 0.75 | | |

Attribute States for Alternative : 2

Cumulative Distribution for StanEval

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 1.0000 | 0.00 | 3.0000 | 0.50 | 3.0000 | 1.00 |
| 2.0000 | 0.25 | 3.0000 | 0.75 | | |

Cumulative Distribution for #ExerciseMissions

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 0.0000 | 0.00 | 4.0000 | 0.50 | 5.0000 | 1.00 |
| 2.0000 | 0.25 | 4.0000 | 0.75 | | |

Attribute States for Alternative : 3

Cumulative Distribution for StanEval

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 2.0000 | 0.00 | 3.0000 | 0.50 | 4.0000 | 1.00 |
| 2.0000 | 0.25 | 4.0000 | 0.75 | | |

Cumulative Distribution for #ExerciseMissions

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 2.0000 | 0.00 | 5.0000 | 0.50 | 7.0000 | 1.00 |
| 4.0000 | 0.25 | 5.0000 | 0.75 | | |

Attribute States for Alternative : 4

---

Cumulative Distribution for StanEval

| State | CDF | State | CDF | State | CDF |
|---|---|---|---|---|---|
| 3.0000 | 0.00 | 4.0000 | 0.50 | 6.0000 | 1.00 |
| 3.0000 | 0.25 | 5.0000 | 0.75 | | |

Cumulative Distribution for #ExerciseMissions

| State | CDF | State | CDF | State | CDF |
|---|---|---|---|---|---|
| 4.0000 | 0.00 | 6.0000 | 0.50 | 8.0000 | 1.00 |
| 5.0000 | 0.25 | 7.0000 | 0.75 | | |

Attribute States for Alternative : 5

---

Cumulative Distribution for StanEval

| State | CDF | State | CDF | State | CDF |
|---|---|---|---|---|---|
| 3.0000 | 0.00 | 5.0000 | 0.50 | 7.0000 | 1.00 |
| 4.0000 | 0.25 | 6.0000 | 0.75 | | |

Cumulative Distribution for #ExerciseMissions

| State | CDF | State | CDF | State | CDF |
|---|---|---|---|---|---|
| 7.0000 | 0.00 | 8.0000 | 0.50 | 10.0000 | 1.00 |
| 7.0000 | 0.25 | 10.0000 | 0.75 | | |

Attribute States for Alternative : 6

---

Cumulative Distribution for StanEval

| State | CDF | State | CDF | State | CDF |
|---|---|---|---|---|---|
| 3.0000 | 0.00 | 5.0000 | 0.50 | 8.0000 | 1.00 |
| 4.0000 | 0.25 | 6.0000 | 0.75 | | |

Cumulative Distribution for #ExerciseMissions

| State | CDF | State | CDF | State | CDF |
|---|---|---|---|---|---|
| 7.0000 | 0.00 | 14.0000 | 0.50 | 18.0000 | 1.00 |
| 9.0000 | 0.25 | 14.0000 | 0.75 | | |

Attribute States for Alternative : 7

---

Cumulative Distribution for StanEval

| State | CDF | State | CDF | State | CDF |
|---|---|---|---|---|---|
| 3.0000 | 0.00 | 6.0000 | 0.50 | 8.0000 | 1.00 |
| 5.0000 | 0.25 | 8.0000 | 0.75 | | |

Cumulative Distribution for #ExerciseMissions

| State | CDF | State | CDF | State | CDF |
|---|---|---|---|---|---|
| 7.0000 | 0.00 | 14.0000 | 0.50 | 18.0000 | 1.00 |
| 7.0000 | 0.25 | 14.0000 | 0.75 | | |

Attribute States for Alternative : 8

---

Cumulative Distribution for StanEval

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 4.0000 | 0.00 | 6.0000 | 0.50 | 9.0000 | 1.00 |
| 5.0000 | 0.25 | 8.0000 | 0.75 | | |

Cumulative Distribution for #ExerciseMissions

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 10.0000 | 0.00 | 14.0000 | 0.50 | 18.0000 | 1.00 |
| 14.0000 | 0.25 | 18.0000 | 0.75 | | |

Attribute States for Alternative : 9

---

Cumulative Distribution for StanEval

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 4.0000 | 0.00 | 8.0000 | 0.50 | 11.0000 | 1.00 |
| 7.0000 | 0.25 | 9.0000 | 0.75 | | |

Cumulative Distribution for #ExerciseMissions

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 14.0000 | 0.00 | 18.0000 | 0.50 | 21.0000 | 1.00 |
| 14.0000 | 0.25 | 21.0000 | 0.75 | | |

Attribute States for Alternative : 10

---

Cumulative Distribution for StanEval

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 7.0000 | 0.00 | 8.0000 | 0.50 | 12.0000 | 1.00 |
| 8.0000 | 0.25 | 9.0000 | 0.75 | | |

Cumulative Distribution for #ExerciseMissions

| State | CDF | State | CDF | State | CDF |
|-------|-----|-------|-----|-------|-----|
| 14.0000 | 0.00 | 18.0000 | 0.50 | 21.0000 | 1.00 |
| 14.0000 | 0.25 | 18.0000 | 0.75 | | |

Attribute States for Alternative : BEENAROUND

---

Point Value for StanEval      =      7.0000
Point Value for #ExerciseMissions     =      18.0000

Attribute States for Alternative : SEENSOME1

---

Point Value for StanEval      =      3.0000
Point Value for #ExerciseMissions     =      18.0000

Attribute States for Alternative : SEENSOME2

---

Point Value for StanEval        =        3.0000
Point Value for #ExerciseMissions      =        7.0000


Attribute States for Alternative : OLDDOG

---

Point Value for StanEval        =       12.0000
Point Value for #ExerciseMissions      =       10.0000



B.   The Preference Inputs for Each Decision Maker

Attribute Preferences for Individual:   DM2

---

Scaling Constraints (Heights) For Each Attribute Are:
StanEval:          0.8632
#ExerciseMissions:          0.1368

The Utility Function for Each Attribute Are:
ATTRIBUTE: StanEval

| State | Utility | State | Utility | State | Utility |
|-------|---------|-------|---------|-------|---------|
| 1.0000 | 0.00 | 7.0000 | 0.50 | 12.0000 | 1.00 |

ATTRIBUTE: #ExerciseMissions

| State | Utility | State | Utility | State | Utility |
|-------|---------|-------|---------|-------|---------|
| 0.0000 | 0.00 | 15.0000 | 0.50 | 21.0000 | 1.00 |

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## Vita

Major Barton H. Wohl ~~was born~~ �-. He graduated from high school in Hazlet, New Jersey, in 1974 and attended the United States Air Force Academy, class of 1978. After graduating with a Bachelor of Science degree, he worked for several months at the Air Force Weapons Laboratory before beginning Undergraduate Pilot Training at Columbus AFB, Mississippi. He completed pilot training and received his wings in October 1979. He then served as a Forward Air Controller and O-2 pilot in the 21st Tactical Air Support Squadron, Shaw AFB, South Carolina from 1980 to 1983. From 1984 to 1985 he was an F-4E pilot in the 57th Fighter Interceptor Squadron, Keflavik, Iceland, and then served as an F-4E pilot, flight lead and flight instructor in the 336th Tactical Fighter Squadron, Seymour Johnson AFB, North Carolina until entering the School of Engineering, Air Force Institute of Technology, in August 1988.

~~Freehold, New Jersey~~

## Vita

Captain Kevin M. Holt ~~born on 24 March 1955 in Phoenix, Arizona~~
He graduated from Beavercreek High School, Beavercreek, Ohio, in 1973.
He entered the United States Air Force in December of 1979, and received
a Bachelor of Science in Mathematic from Saint Edward's University,
Austin, Texas, in December of 1984, while stationed at Bergstrom AFB.
He was commissioned through Officer Training School in October 1985, and
was subsequently assigned to the 28 Air Division at Tinker AFB,
Oklahoma, as an AWACS Operations Research Analyst.  He entered the
School of Engineering, Air Force Institute of Technology, in August
1988.

P~~ermanent address:~~

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The purpose of this research was to define an appropriate tool to assist AWACS personnel managers in determining the personnel acquisitions that are required for AWACS operations. The approach used to structure the decision process was that of a Decision Support System (DSS). The goal of the specified DSS was to provide an initial point to better state personnel acquisition requirements, particularly with regard to the experience of the crew force, and to provide a structure for improvement in the DSS itself.

The decisions supported by the designed DSS go beyond what has been attempted by AWACS air crew managers in the past, explicitly addressing experience level inventories and the need to stabilize both manning levels and experience levels in the various AWACS crew positions. The overall design of the DSS to support these goals is specified through the mechanisms of concept mapping and storyboarding, and a kernel system is developed. Adaptive design is adopted as the means for continued system development and evolution.

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